Metal Working

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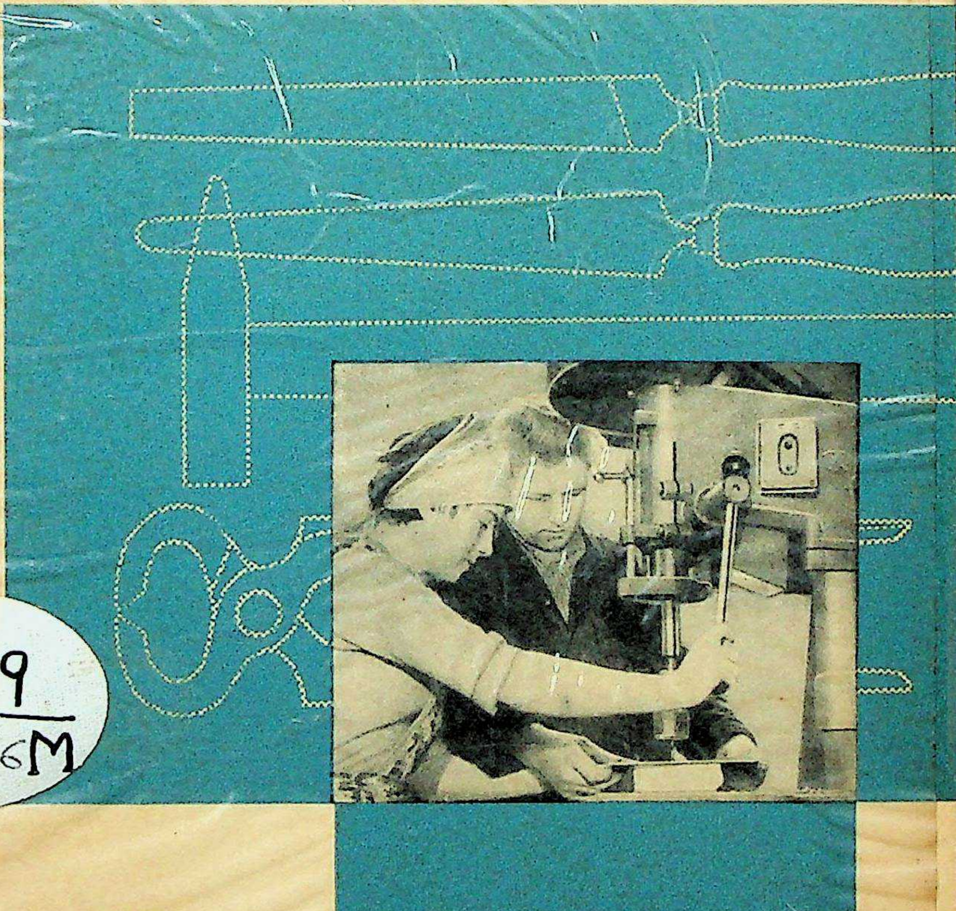

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TECHNICAL FUNDAMENTALS

Metal Working

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Metal Working

BY HEINZ GRAFF

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A WORD OF INTRODUCTION

Wherever you go, you come across things of metal. The lumberman cannot do his job in the forest without a sharp-edged axe. When building roads, the workers need shovels and picks.

Machines, instruments, and tools used in the industries consist mainly of iron and steel, that is, metals are used as material. The same applies to traffic. Ships, aeroplanes, railways, motor-vehicles, and bicycles can only be built because men know how to work metals.

The lumberman's axe consists only of a wooden helve and a metal head made by the blacksmith, whereas machines and instruments used in the industries, and the means of communication are made up of many prefabricated parts of different shapes. A great number of these parts are made of rods, tubes, and sheet-metal, the so-called *half-finished goods*. Great manual skill is required to make the parts well enough to meet all requirements both as to shape and properties.

Naturally, prefabricated parts are not only made by hand. There are modern machines designed to help men and which perform the job quicker and more accurately. Anyone who wishes to handle such a machine properly, must know about the fundamental skills in metal working and command some of them.

This book starts from scratch, presuming no or very little experience and theoretical knowledge on the part of the reader. Therefore, it is necessary to start from *checking* and *marking*. Only he who repeatedly checks his work, especially as to dimensional accuracy, will be in a position to achieve high-quality work. Marking as a necessary condition of dimensionally accurate work plays an important part in this connection.

The following chapter describes *cutting*, starting from chisel work as the most elementary working method. However, this chapter deals also with cutting by means of the drill and goes already into details of handling a drilling machine, because experience has shown that drilling should in any case be included in the fundamental skills of metal working.

The chapter on *forming* deals only with manual skills. We could not do without a number of tables which are included in this chapter to clarify the interrelations as far as possible.

The last chapter of this book is devoted to *joining*. The screw connections and rivet joints which are generally used in practice, and soft soldering are dealt with in this section.

These operations form the practical basis and are significant of quite a number of technical trades. No one will be in a position to specialise in a certain line without mastering them thoroughly.

The essential fundamental skills of metal working can easily be grasped even by the reader who does not command elementary technical knowledge. In general mathematical and physical explanations are left out. However, mathematical explanations and examples are indispensable in certain jobs, for instance, the execution of rivet joints. These explanations are printed in small types and are designed to help and incite the reader. Numerous pictures illustrate the text and considerably facilitate the grasping of the technical interrelations.

The diversity of operations demanded of the workers in the metal working industry has led to a very far-reaching specialisation. The modern industry counts almost 80 special lines all of which are built up on the fundamentals treated in this book. However, they call for further specific abilities and knowledge. Included in these special trades are turners, welders, electricians, machinists, machine fitters, and motorcar mechanics, to mention but a few.

We intend to explain in a similarly popular way the specific operations involved in metal working, such as turning, planing, milling, welding, and grinding in future books. In addition, such important subjects as the construction of jigs and fixtures, rivet and screw joints, care and maintenance of machines, and the reading of technical drawings will also be treated.

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Checking and marking

A. CHECKING

Checking is done by comparison with a measure or a standard

I. COMPARING WITH A MEASURE

Checking by way of comparing with a measure is called measuring; to this end measuring tools are used. Measuring tools may be sub-divided into (1) non-adjustable measuring tools and (2) adjustable measuring tools. Non-adjustable measuring tools are available with or without graduation; tools of the latter type are usually called *gauges*. Adjustable measuring tools are nearly always provided with a graduation.

The units used for graduation in the case of *linear measurements* are mainly:

Millimetres (mm.),

10 mm. = 1 cm.
100 mm. = 10 cm.
1000 mm. = 100 cm. = 1 m.

In some countries, also inches (″) are used for linear measurements:

1″ = 25.4 mm.
5″ = 127.0 mm.
10″ = 254.0 mm.
12″ = 304.8 mm.

Inches are indicated by proper fractions:

½″ = 12.7 mm.
¼″ = 6.35 mm.
⅛″ = 3.175 mm.
⅜″ = 9.525 mm.

or by mixed numbers:

1½″ = 38.1 mm.
2¼″ = 57.15 mm.
4½″ = 104.779 mm.
3⅜″ = 85.73 mm.

1. Non-adjustable measuring tools

Steel tape measure

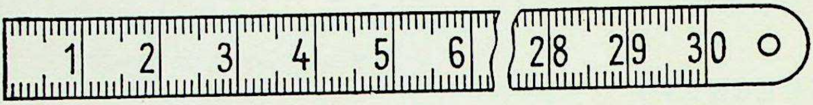


Fig. 1 Length 300 mm.

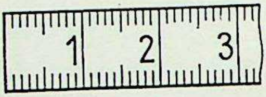


Fig. 2 The 1-millimetre graduation is usual

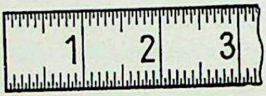


Fig. 3 The 0.5-millimetre graduation is too fine and would lead to reading errors

Proper handling

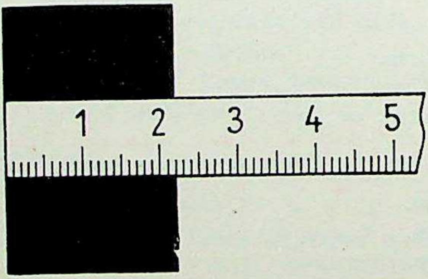


Fig. 4 The reference edge coincides with the tape measure start mark

Wrong handling

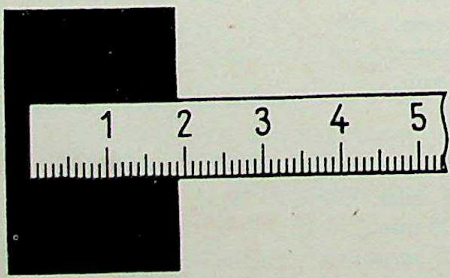


Fig. 5 The reference edge does not coincide with the tape measure start mark

Fig. 6 The reference edge does not coincide with the tape measure start mark

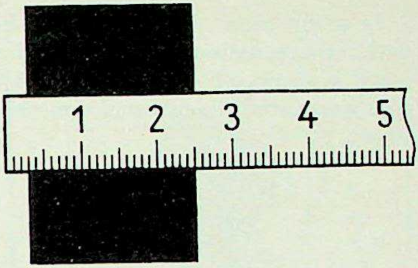
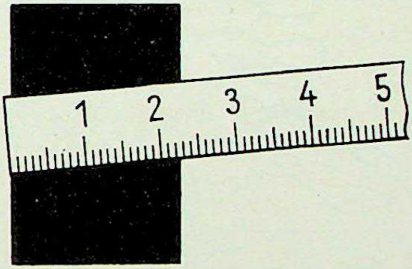


Fig. 7 The steel tape measure has not been placed straight



Folding rules

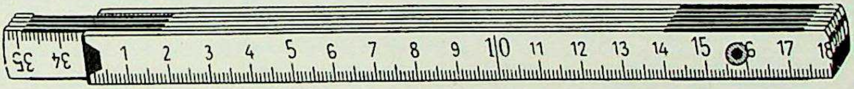


Fig. 8 Folded

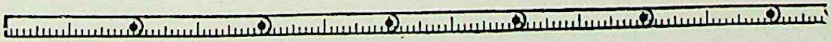


Fig. 9 Stretched out

Folding rules consist of wood or metal and are 1,000 mm. or 2,000 mm. long. Measurements obtained with the aid of folding rules are usually too inaccurate for metal working; they should only be used to measure lengths in the rough.

Wrong handling

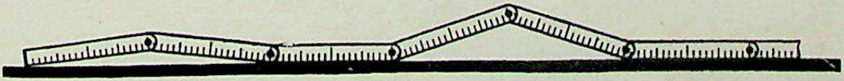


Fig. 10 The reading gives a length greater than the actual length

In many cases the checking of dimensions or shapes by measuring tools without graduation saves time. Thus, for example, the thickness of sheet metal is checked by means of the *plate gauge*, wire diameters by means of the *wire gauge*, and the external dimensions of work pieces by means of the *snap gauge*.

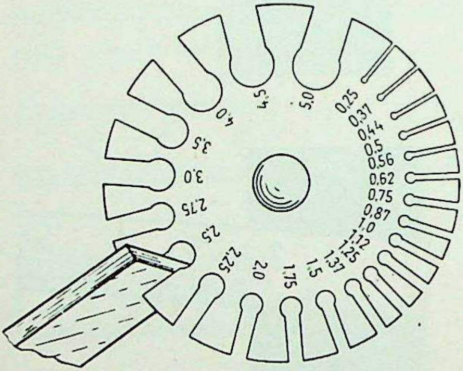

4.0
4.5
5.0
0.25
0.37
0.44
0.5
0.56
0.62
0.75
0.87
1.0
1.12
1.25
1.37
1.5
1.75
2.0
2.25
2.5
2.75
3.0
3.5

Fig. 11 A German plate gauge

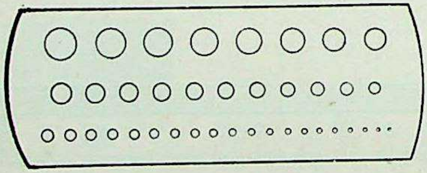


Fig. 12 Wire gauge; checking range from 0.1 mm. to 10 mm.

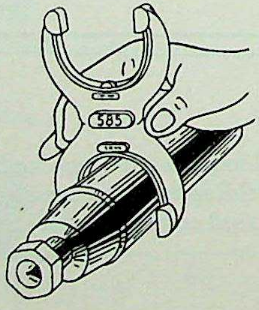


Fig. 13 Snap gauge

If it is desired to ascertain whether two work piece edges are at right angles, usually a solid *steel square* or a *back square* is used. To check mitre cuts, a *mitre square* is used which is set at 45°.

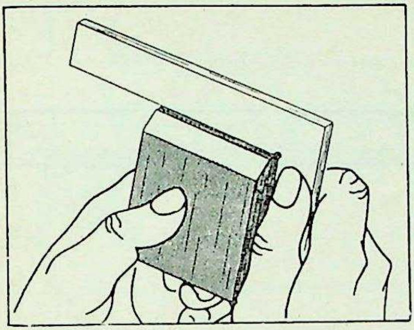


Fig. 14 Solid steel square

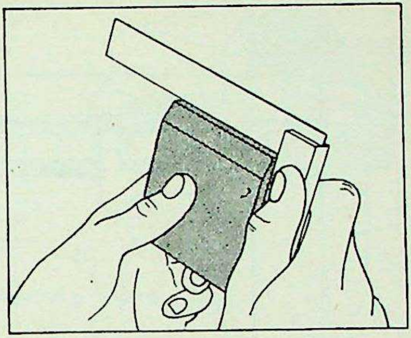


Fig. 15 Back square

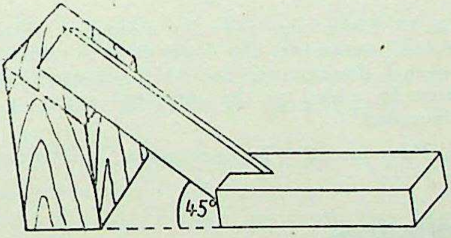


Fig. 16 Mitre square

2. Adjustable measuring tools

The adjustable measuring tools most frequently used in metal working for linear and angular measurements are the *sliding caliper* and the *protractor*. The sliding caliper may be used either for checking dimensions, i.e. measuring, or for checking without taking the measure, i.e. comparing. In the latter case it functions as a gauge.

Sliding caliper

The sliding caliper consists essentially of a firm jaw with a steel rule, and an adjustable jaw with a slide. The adjustable jaw can be locked by means of a fixing clamp or a set screw.

Operating principle and jaw shapes of the sliding caliper.

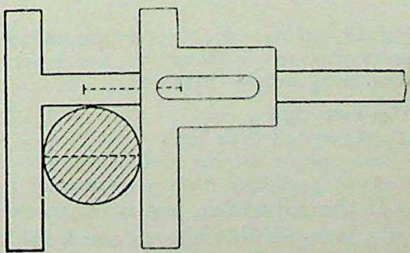


Fig. 17 Operating principle of the sliding caliper

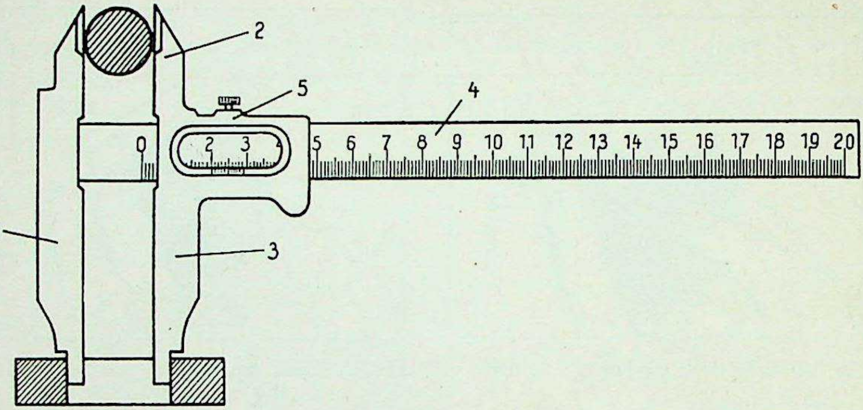

2
5
4
0
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1
3

Fig. 18 Knife edge jaws for measuring outside diameters are provided at the top of the instrument. The lower part is provided with measuring jaws for checking internal dimensions; the width of each jaw is 5 mm. This means that 10 mm. must be added to the indicated value in order to obtain the actual internal dimension.

= Firm jaw; 2 = Knife edge jaw; 3 = Adjustable jaw; 4 = Steel rule; 5 = Set screw

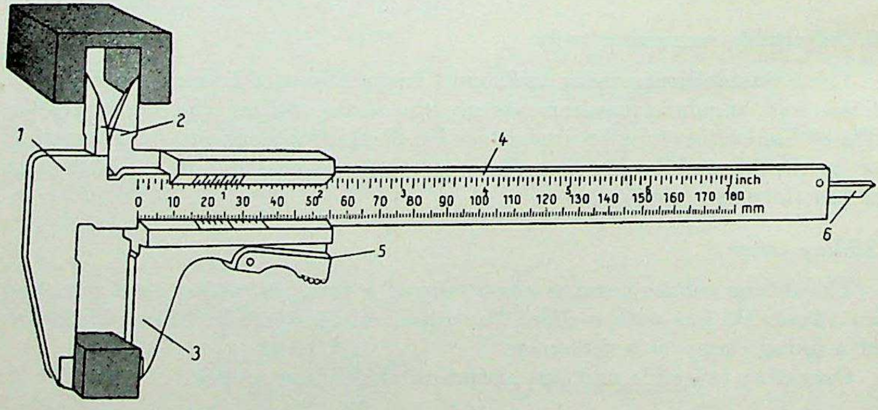

2
1
4
inch
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
mm
6
5
3

Fig. 19 At the top, this sliding caliper is provided with cross-bill type jaws for measuring inside diameters; the lower part is provided with knife edge jaws for measuring outside diameters.

1 = Firm jaw
2 = Cross-bill type jaws
3 = Adjustable jaw
4 = Steel rule
5 = Setting clamp
6 = Depth gauge

If the adjustable jaw is connected to a tongue sliding in a groove of the rule, it is possible also to check the depth of a bore.

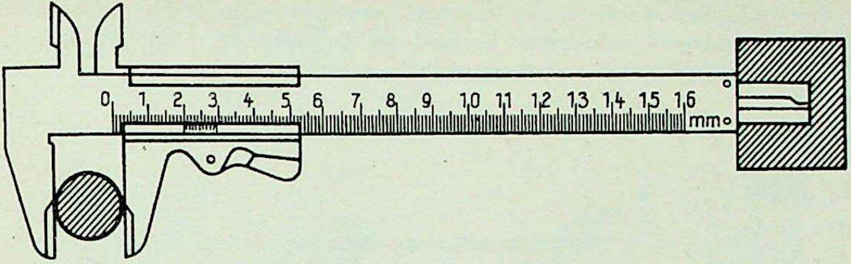


Fig. 20 Checking the depth of a bore by means of a sliding caliper

The reading of measurements

The open part of the slide is called the "window" and may differ in its shape (see Figs. 18 and 19). The chamfered edges of the window are always provided with a graduation which, in order to distinguish it from the main scale on the rule, is called the auxiliary scale or vernier. As a rule, by using the vernier, a measuring accuracy of 0.1 mm. can be attained.

If the millimetre is used as a unit, the vernier usually has a length of 9 mm. and is sub-divided into 10 parts, each measuring 9/10 mm.

When the jaws of the sliding caliper are closed (zero position), the zero mark of the main scale coincides with the first mark of the vernier, while the first graduation mark of the main scale no longer coincides with the first graduation mark of the vernier, the two being spaced apart by a distance of 1/10 mm. Between the second graduation mark of the main scale and the second graduation mark of the vernier, there will be a gap of 2/10 mm., and between the fourth graduation mark of the main scale and the fourth graduation mark of the vernier a gap of 4/10 mm. Only the 9th graduation mark of the main scale will again coincide with the tenth vernier mark.

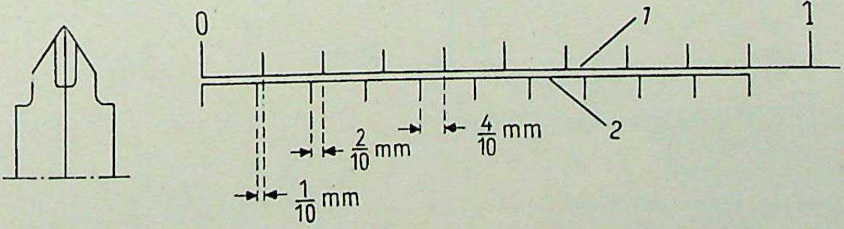


Fig. 21 Main and auxiliary scales (vernier), with the sliding caliper in the zero position. The main scale is shown on top and the auxiliary scale (vernier) at the bottom.

1 = Main scale; 2 = Vernier

If a work piece of a dimension less than 1 mm. is to be checked by measuring, then the measured value must be read off the point where the graduation marks of the main scale and those of the vernier coincide.

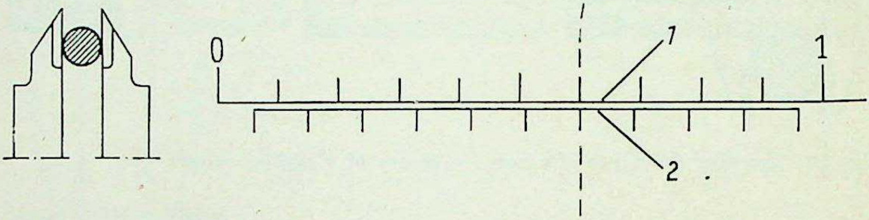


Fig. 22 Reading the value of 0.6 mm. 1 = Main scale 2 = Vernier

If a work piece is measured whose dimension exceeds 1 mm., the full millimetres are determined first; they are indicated by the first millimetre mark situated to the left of the first vernier mark. Then the two graduation marks of the main and the auxiliary scales are to be found which coincide within the vernier region, whereupon the number of the vernier marks situated between this point and the first vernier mark are to be counted. The number of marks counted indicates the value in tenths of a millimetre which must be added to the number of full millimetres in order to obtain the correct measure.

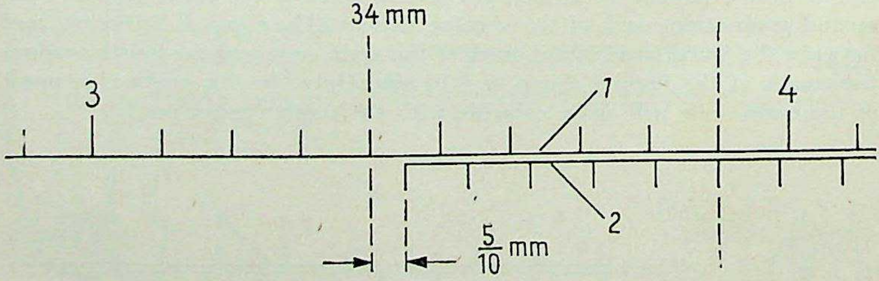


Fig. 23 Reading the value of 34.5 mm. 1 = Main scale 2 = Vernier

Reading error (parallax)

When handling calibrated measuring tools, wrong values are frequently obtained if the value is read obliquely. If the measuring tools have a chamfered edge, with the graduation marks reaching the edge of the measuring tool, such reading errors can be largely avoided.

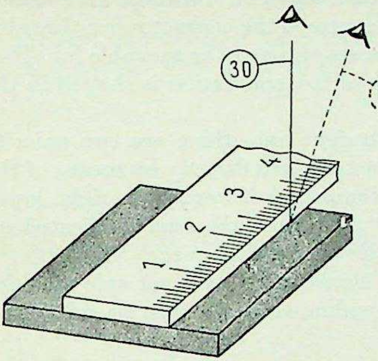


Fig. 24 Reading error with a non-chamfered rule

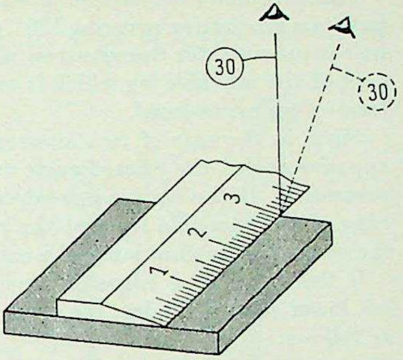


Fig. 25 Reading errors are avoided by chamfering the edge of the rule

Protractor

The unit of measure for angular measurement is the "degree" (symbol °).

A circle is subdivided into 360 degrees (360°)
A right angle = $^1/_4$ of a circle and therefore has 90°
1° is subdivided into 60 minutes (60′)
1 minute is subdivided into 60 seconds (60″)

When the edges of a work piece form an angle which deviates from the usual angles (90°, 45°), this angle may be determined with the aid of an adjustable protractor. Besides, such a protractor may also be used for marking when the marking lines do not form one of the usual angles. This will be explained in more detail later on.

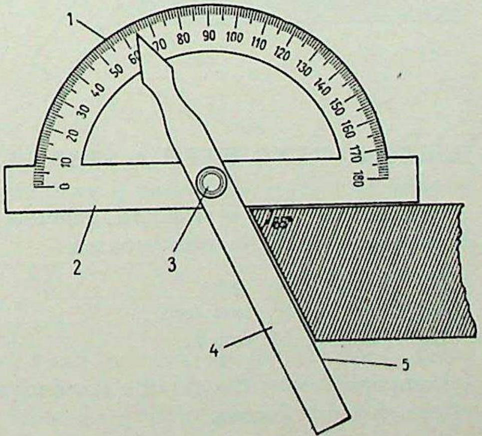


Fig. 26 Adjustable protractor applied to a work piece for direct reading of the angle

1 = Protractor head
2 = Contact rule
3 = Set screw
4 = Movable leg
5 = Right edge of leg

The protractor consists of a semi-circular segment, the protractor head, having a graduation covering 180°. In the centre of the contact rule a threaded hole is provided for the set screw which passes through the movable leg. That part of the movable leg which is to ply over the graduation is shaped in the form of an arrow-head.

Since in the case of two intersecting straight lines there are two pairs of opposite angles, the wanted angle may be determined directly by means of the protractor. If the work piece edges are comprised between the right lower edge of the movable leg and the contact rule, then the angle indicated on the protractor graduation is the actual angle of the work piece.

If the work piece edges are comprised between the contact rule and the left lower edge of the leg, the value of the unknown angle must be calculated as follows.

180° – degrees indicated = actual degrees

(If the enclosed angle is, for example, read as 54°, then it is actually 180° — 54° = 126°.)

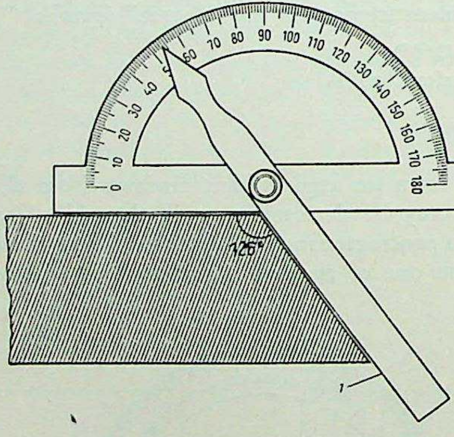


Fig. 27 Placing a protractor on the work piece for indirect angle reading

1 = Left-hand side of leg

II. COMPARING WITH A STANDARD

Comparison with a standard amounts to checking without measuring. It is possible to distinguish between

(1) Checking by eye
(2) Checking by ear, and
(3) Checking by touch.

Comparison with the aid of a standard requires a certain skill on the part of the checking person.

1. Checking by eye

A visual check allows to compare the outer shape of a work piece or its surface quality with a standard.

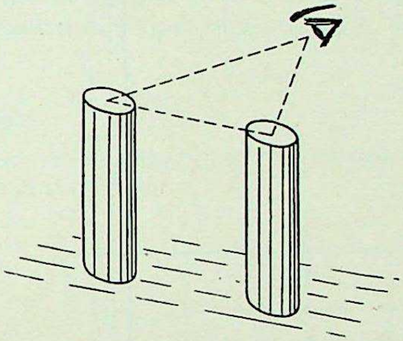


Fig. 28 Comparing a work piece with a standard

2. Checking by ear

Split or cracked work pieces can be judged by sound. It is also possible to distinguish hard from mild steel by sound.

Checking by sound is done in the same way as with glass, porcelain or ceramic containers. Faultless work pieces ring true when knocked.

3. Checking by touch

When a work piece is treated with a file, the result is a file mark. The type of file chosen for the work determines the quality of a surface which can be classified into finishing characteristics such as "rough", "fine" and "very fine". The treatment given to a certain surface may be ascertained by touch. On "fine" surfaces, the file mark should no longer be discernible by touch, while it may still be visible.

B. MARKING

Marking is a preparation for the mechanical treatment of a work piece. Marking means the transfer to the work piece of measurements from the drawing by marking lines and gauge points.

I. MARKING METHODS

The kind of work piece to be treated and the working methods to be applied to it, will largely determine the choice of the marking procedure. The marking procedures may be distinguished as follows: (1) Marking out from one reference

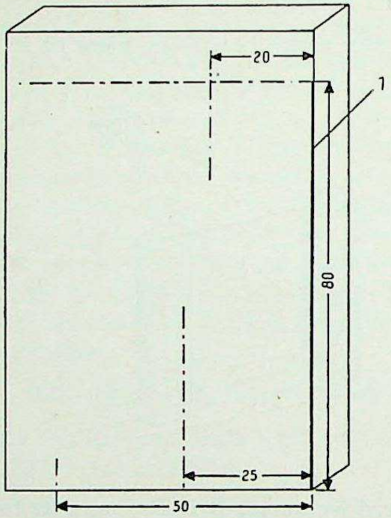


Fig. 29 Marking out dimensions on a work piece from a reference edge. The auxiliary dimension lines are marked out from the reference edge by means of a back square.
1 = Reference edge

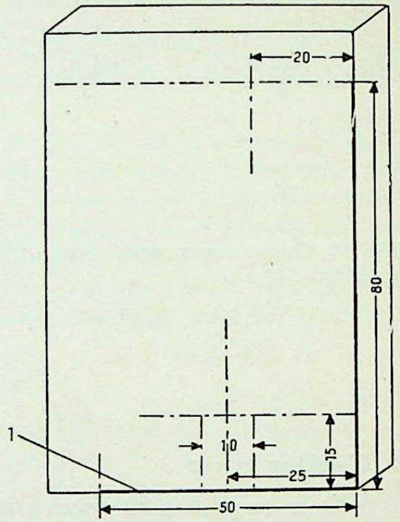

20
80
1
10
15
25
50

Fig. 30 Using a second reference edge
1 = Second reference edge

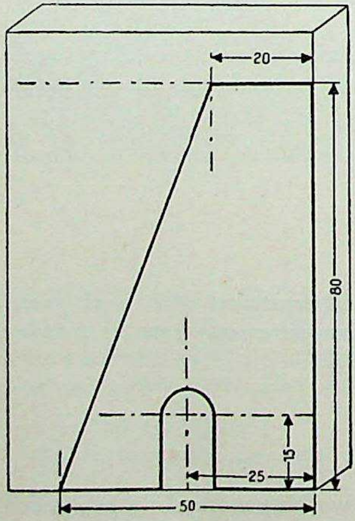

20
80
15
25
50

Fig. 31 Marking out all edges and the semi-circle

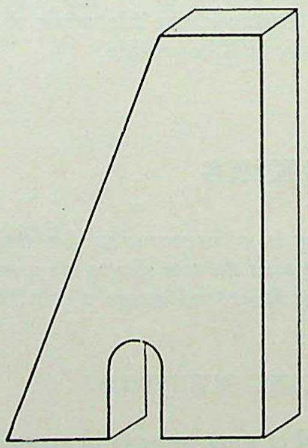


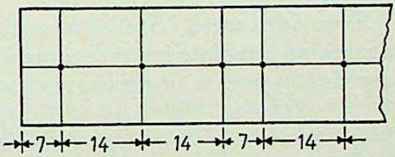
Fig. 32 Finished work piece

edge, (2) Marking out from one reference edge and one reference line, (3) Marking out from one reference surface, and (4) Marking out by means of a template. This subdivision does not preclude a combination of several marking procedures, in accordance with the complexity of a work piece, or the necessity of having to mark in relation to several reference edges, lines or surfaces.

1. Marking out from one reference edge

It is necessary to prepare a reference edge on the work piece so that the required tools can make perfect contact therewith.

Fig. 33 Marking out dimensions in the wrong way! Accurate marking is not possible by transferring a chain of measurements; in this way marking errors will accumulate.

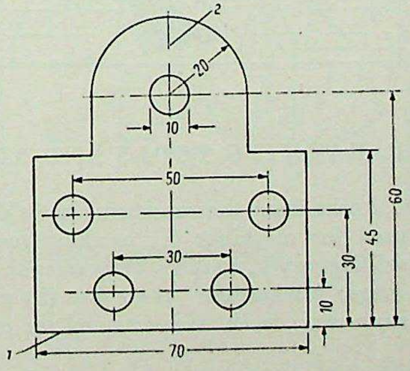


2. Marking out from one reference edge and one reference line

Work pieces which have not only edges but also rounded portions, can often be marked more easily by using a reference edge and a reference line. In the case of symmetrical components, the centre line is chosen as the reference line for marking.

Fig. 34 Marking out dimensions on a work piece from one reference edge and one reference line (in this case the centre line).

1 = Reference edge
2 = Reference line



3. Marking out from one reference surface

To mark out from one reference surface, the work piece is placed on a plane, called the *surface plate*, which will be described later. In relation to this surface, the marking lines are applied by means of a *surface gauge*.

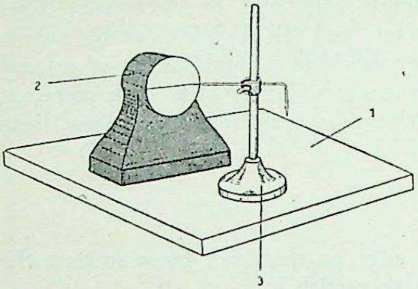


Fig. 35 Marking out from a reference surface

1 = Surface plate
2 = Work piece
3 = Surface gauge

4. Marking by means of a template

Even with small batches of work pieces it is often of advantage to make a marking template instead of marking each individual piece according to the drawing by means of measuring tools.

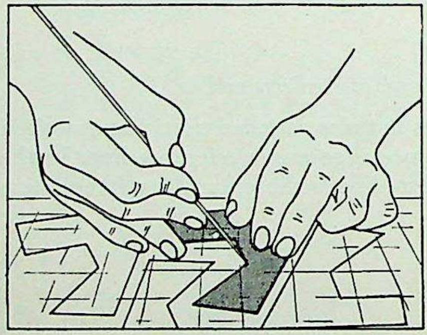


Fig. 36 Marking out an outline by means of the marking template

II. MARKING TOOLS AND AUXILIARIES

Apart from the measuring tools described earlier, the following tools are used for marking: (1) marking tools such as *the scriber*, *marking punch*, *drilling punch*, *dividers*, *beam compasses*, *scratch gauge*, *height gauge* and *surface gauge;* furthermore, there are (2) auxiliaries such as the *surface plate*, *V-supports*, *parallel supports* and *the centre square*.

1. Marking tools

When using marking tools, marking lines and gauge points can be applied visibly and durably to the work piece. Marking lines are sub-divided into lines scratched into, and lines applied on to the surface. Usually, the lines are scratched into the surface, i.e. marking is carried out with a material harder than the work piece. Lines applied on to the surface are obtained if, for example, brass is employed for the application of marking lines to steel-made work pieces with finely finished surfaces.

On thin brittle sheets, marking lines can be applied by means of soft pencils, since the notching effect of the marking tool must be avoided.

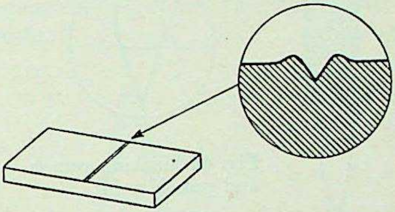


Fig. 37. Notching effect of the marking tool

The Scriber

Scribers are available in various shapes. Fig. 38 shows a frequently used form of scriber whose point should be protected by a cork. Scribers having two points (of which one is usually angled) often lead to accidents. To obtain a correct marking line, it is essential that the scriber is applied and guided properly.

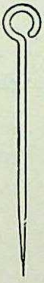


Fig. 38 Scriber

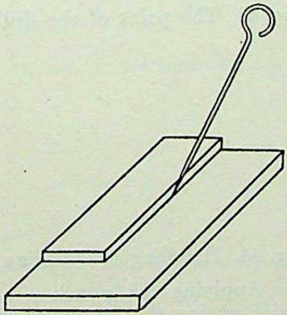


Fig. 39 How to apply the scriber

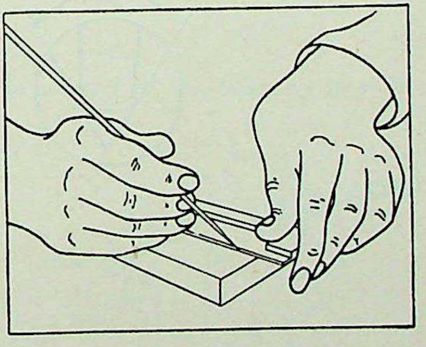


Fig. 40 Guiding the scriber

The marking punch

If a work piece is to be divided, for example, along a marking line, then gauge points become necessary. The gauge points are made along the marking line by slight hammer blows on the marking punch. Corners are marked by one gauge point, straight lines by a number of gauge points at large intervals, curved lines by gauge points with a closer spacing. The tapered point of the marking punch has an angle of usually 40°.

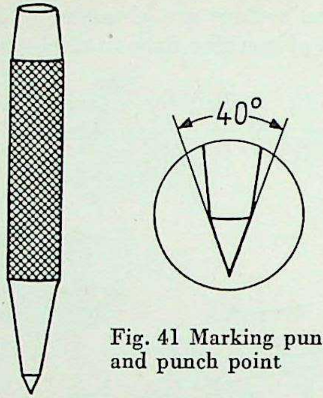


Fig. 41 Marking punch and punch point

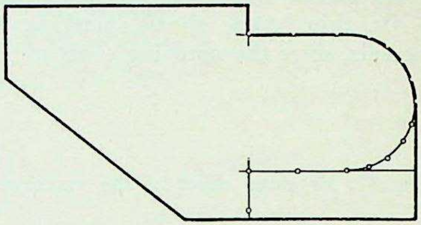


Fig. 42 Gauge points on the marking lines; if the work piece is treated carefully, point halves should remain visible

Drilling punch

If drilling points are to be marked, the drilling punch is used. Its point has an angle more obtuse than that of the marking punch point, this angle usually being 60°. A strong blow of the hammer is needed to mark the point. The wide cone of the drilling punch facilitates the application of the drill.

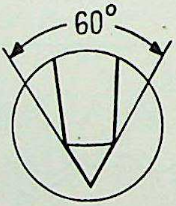


Fig. 43 The point of the drilling punch

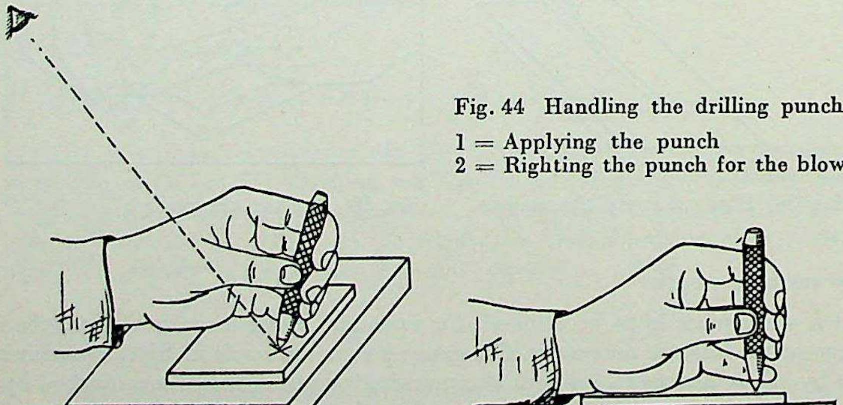


Fig. 44 Handling the drilling punch

1 = Applying the punch
2 = Righting the punch for the blow

The dividers

The dividers may be used to mark off circles or part-circles and subdivisions on straight or curved lines. When using the dividers, the starting point must in every case be a gauge point. The dividers are to be adjusted to the desired measure with the aid of the steel tape measure; since errors may originate already at this stage it is indispensable to check the marked-off dimensions before punching the gauge points.

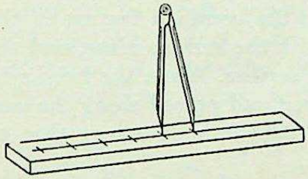


Fig. 45 Subdividing a straight line

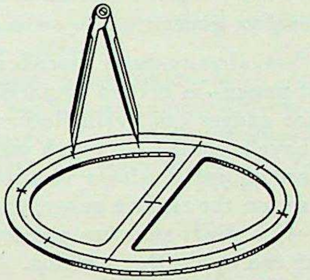


Fig. 46 Subdividing a circle; not until the last divisions coincide the gauge points should be punched

The beam compass

If larger circles or part-circles are to be marked off, the beam compass is used.

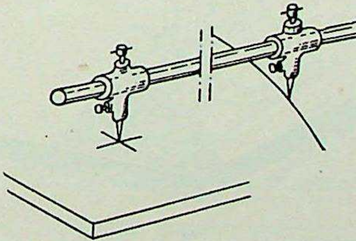


Fig. 47 The beam compass

The scratch gauge

If markings are to be made parallel with an edge already finished, then the scratch gauge can be used to advantage. As in the case of the dividers, the required dimension is set by means of the steel tape measure; attention is drawn to the fact that the height of the scratch gauge point must be set in accordance with the height of the work piece.

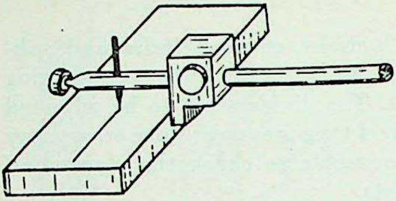


Fig. 48 The scratch gauge

The surface gauge

As has already been described on page 21, a surface gauge – also called height gauge – is needed if marking out from a reference surface is required. Surface gauges are available in various forms; the common feature is that they have a plane base which makes contact with the surface plate, and that they are equipped with a vertically adjustable scriber. When the height has been set on the surface gauge, the base is gripped and passed along the work piece with slight pressure against the surface plate in such a way that the scriber can apply the marking.

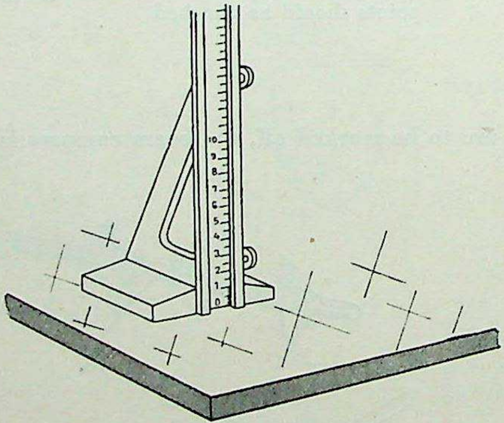


Fig. 49 Height gauge; the surface gauge can easily be set to the desired height

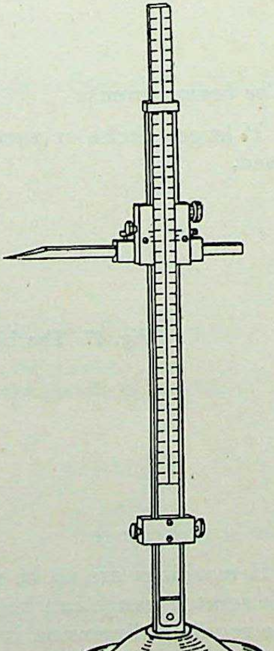


Fig. 50 Surface gauge with scale; a surface gauge of this type allows rapid setting to the desired height

2. Marking auxiliaries

Quite a number of auxiliaries are necessary in view of the different and in itself not uniformly shaped work pieces, and the necessity of accurate markings. The following auxiliaries are frequently used.

The surface plate

The surface plate is made of grey cast iron, its surface being flat and slightly grooved. The grooves facilitate the displacement of the surface gauge; also, work pieces with a fine surface finish cannot adhere.

The surface plate should be well and reflection-free illuminated and rest horizontally on a firm support, the working height being about 800 mm. from the floor. The surface plate serves exclusively for marking purposes; its employment as a levelling or mounting plate will soon render the surface plate useless for accurate marking work.

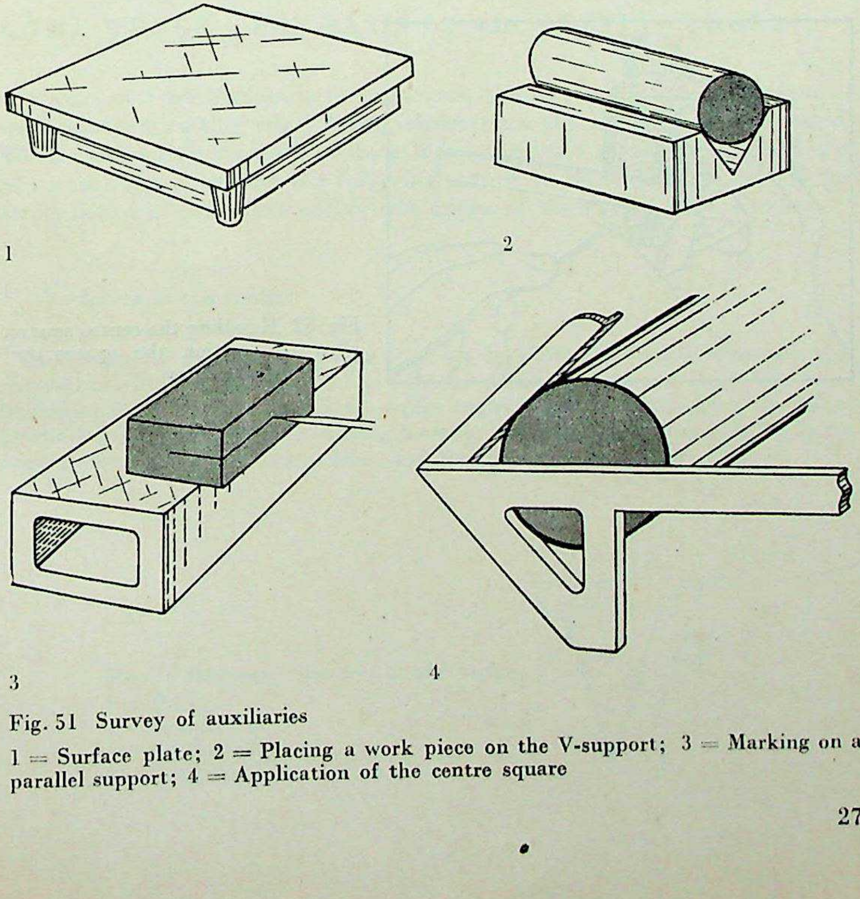


Fig. 51 Survey of auxiliaries

1 = Surface plate; 2 = Placing a work piece on the V-support; 3 = Marking on a parallel support; 4 = Application of the centre square

The V-support

Roundly shaped work pieces which are to be marked are placed on V-supports. In this way they are firmly supported in a horizontal position and cannot rotate easily.

The parallel support

Parallel supports are, for example, used to mark at low levels. They are of square or rectangular shape. Parallel supports are placed under the work piece; their over-all dimensions are such that the marking height can easily be calculated.

The centre square

To mark for example the centre of a shaft, a centre square is used. Care must be taken to establish proper contact with the work piece. When the first line is marked off, the shaft should be turned so that a second marking line can be drawn at approx. 90° to the first one.

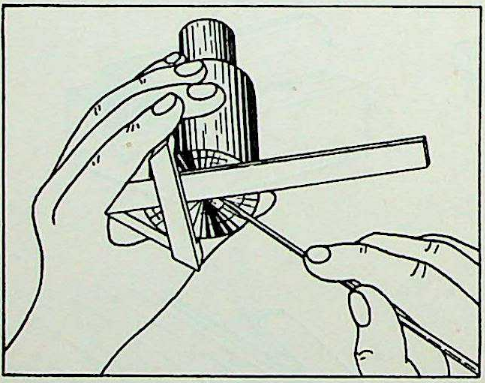


Fig. 52 Handling the centre square. How to position the square and draw marking lines

C. CUTTING BY MEANS OF A CHISEL

Chiselling serves for parting work pieces or detaching cuttings; nowadays it is only used whenever modern machining methods cannot be applied for economical or technical reasons.

I. THE WEDGE – THE BASIS OF ALL CUTTING EDGES

If part of a work piece is to be cut off, this is usually done by means of wedge-shaped cutting edges being harder than the material to be treated. When considering the wedge which forms the basis of the different shapes of cutting edges, we find the following factors to be of importance: (1) the forces acting at the wedge and (2) the angles of the cutting edge.

1. The forces at the wedge

In a wedge we distinguish between the back on which the driving force acts, and the two lateral faces which penetrate into the material as cutting faces. The angle formed by the two lateral faces is the wedge angle. Dynamic relationships, illustrated by the following sketches, are existing between the force acting upon the back, the angle formed by the two lateral faces, and the length of the cutting edge.

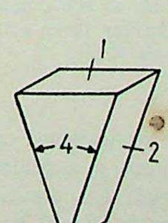


Fig. 53 Reference numbers on the wedge
1 = Back
2 = Lateral face
3 = Cutting edge
4 = Wedge angle

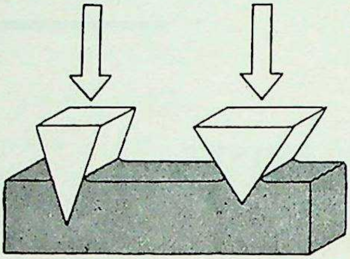


Fig. 54 Depth of penetration with different wedge angles, the driving force and the length of the cutting edge being equal

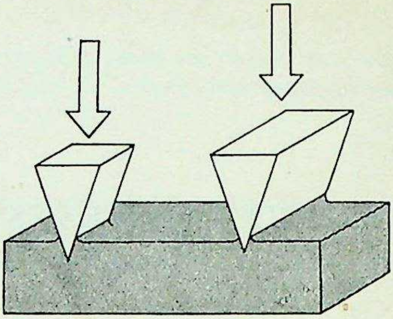


Fig. 55 Depth of penetration with cutting edges of different length, the driving force and the wedge angle being equal

2. The angles at the cutting edge

The cutting edge must be positioned at certain angles with the surface of the material. This angle is being dependent on the kind of work to be done by the edge, that is to say, whether it is to part, to detach cuttings from, to cut or scrape the material.

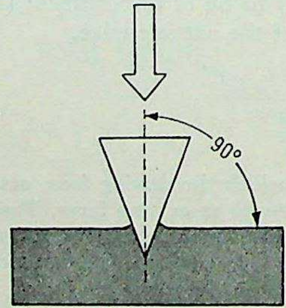


Fig. 56 Position of the cutting edge in parting; the driving force acts upon the back at an angle of 90°

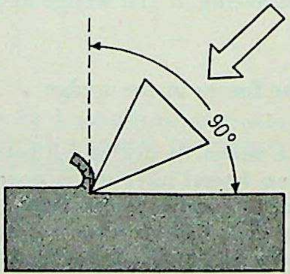


Fig. 57 Position of the cutting edge when metal chips are detached (cutting); the driving force acts upon the back at an angle of 90°

The different ways of cutting material by means of cutting edges often require different positioning of the cutting edge in relation to the surface of the material. The main reasons for different positions of the cutting edge are to reduce frictional heat during cutting and to obtain the desired size of the chip to be detached from the material.

II. THE CHISEL

Today, the chisel is almost exclusively used for repairing, finishing, and preparatory work.

1. The design of the chisel

The chisel is subdivided into *cutting edge*, *shank* and *head*. Metal working chisels should have a length sufficient to allow the shank to be gripped properly. Short chisels are difficult to handle and may lead to accidents through hammer blows if the head projects insufficiently beyond the gripping hand. Excessively long chisels, on the other hand, may vibrate and therefore break easily, and cannot be guided so well.

The cutting edge of the chisel is hardened, while its head is not. Thus, when the chisel is used for any length of time, a ridge forms on its head which is called a "burr". This burr needs to be removed because it may lead to accidents; the ridge causes the hammer to impact inaccurately and thus to glide off, while splinters from the ridge may lead to injuries (particularly to the eye).

Fig. 58 Design of the flat chisel
1 = Cutting edge; 2 = Shank; 3 = Head

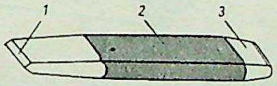
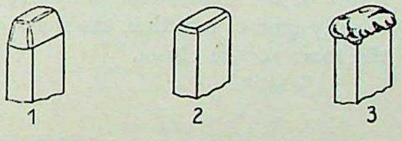


Fig. 59 Chisel heads



1 = Correct shape of chisel head; it is crowned

2 = Wrong shape of chisel head; it is flat, the hammer glances off

3 = Burr-formation at the chisel head; risk of accidents!

2. The action of the chisel

The chisel can be used for parting (cutting-off) or detaching metal-cuttings. The positioning of the chisel is here of decisive importance (see Figs. 56 and 57). In both cases, the action is basically the same; first the cutting edge notches the material (beginning of cut), then it upsets the material so that weals are formed and, upon further penetration, the material is torn apart.

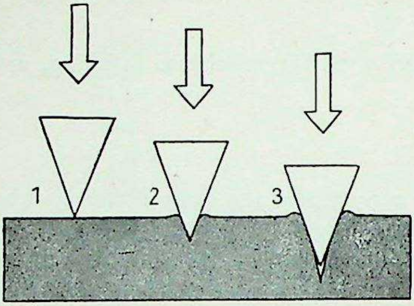


Fig. 60 Chisel action during cutting

1 = Notching

2 = Penetrating and upsetting

3 = Tearing

Upsetting and tearing of the material leads to a structural change in the material at the cut. This change causes a loss of material which must be taken into account when calculating the raw length.

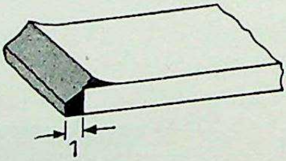


Fig. 61 Structural change at the cut

1 = Loss of material

Proper handling of the chisel or, in other words, the proper utilization of its action also depends on the force of the hammer blows. This force is the result of the expendend muscular force and the mass of the hammer. It is usually true to say that the mass of the hammer should be twice as large as the mass of the chisel.

III. WORKING WITH THE CHISEL

When working with the chisel, care must be taken that the work piece cannot yield or vibrate during cutting. Flat or thin work pieces are placed on a strong support plate, and heavy thick work pieces clamped in a vice or by other means. Three of the many possibilities of parting material by means of a flat chisel are explained below, namely (1) parting flat-bar steel, (2) parting square sections, and (3) parting sheet-metal strip.

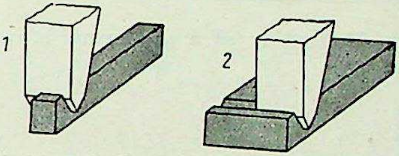
1. Parting flat-bar steel

The flat-bar steel is placed on a support plate. This plate should rest, if possible, above a bench leg so that it cannot vibrate.

First the work piece is notched along the parting line by slight hammer blows on the chisel.

Note the following points: (1) If the cutting edge of the chisel is longer than the width of the work piece, it should project by equal amounts on both sides; (2) If the cutting edge of the chisel is shorter than the width of the work piece, then the work piece must first be notched over its whole width. When notching has been completed, the hammer blows may become heavier to perform the cutting operation.

Fig. 62 Parting flat-bar steel



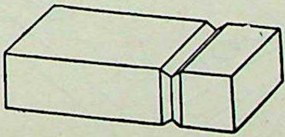
1 = The cutting edge of the chisel projects by equal amounts

2 = A notch is made over the whole width of the work piece

2. Parting square sections

Square sections are parted by equal action from all sides, that is to say, the section is first notched on four sides and then uniformly upset, whereupon the chisel is driven in uniformly until the work piece is parted. Cutting from all sides has the advantage of saving (1) energy, (2) material, and (3) time.

Fig. 63 Steel section, notched on all sides



3. Parting sheet-metal strip

If strips are to be cut from sheet, the sheet is clamped in a vice. When resting on the jaw of the vice, the chisel can be guided more conveniently and cannot slip off too easily. The work piece must be clamped in such a way that it cannot vibrate at the working point, that is to say, long sheet-metal strips must repeatedly be shifted in the vice.

In parting sheet-metal strips, the chisel is held against the work piece in an inclined position so that the full length of the cutting edge should not penetrate the material at once.

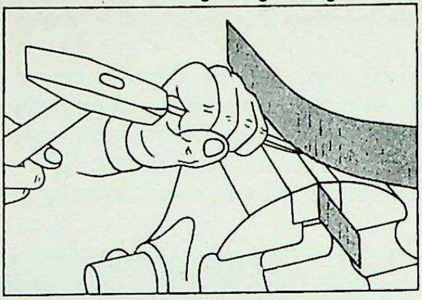


Fig. 64 Cutting off a sheet-metal strip

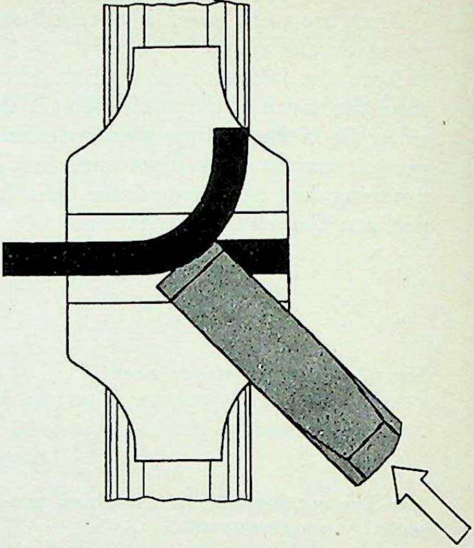


Fig. 65 Correct position of the chisel during cutting

IV. SURVEY OF CHISEL TYPES AND THEIR APPLICATION

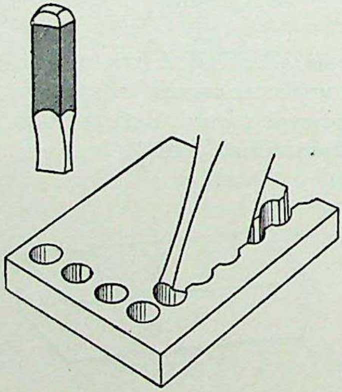


Fig. 66 Butt chisel, cutting through a perforation

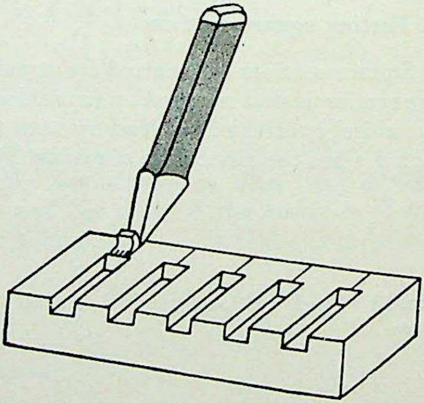


Fig. 67 Cape chisel: cutting out grooves in preparation for the removal of a thick layer

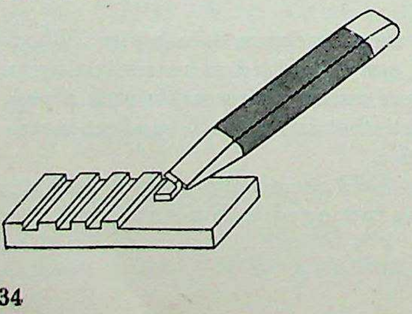


Fig. 68 Removing the residual raised portions with the flat chisel

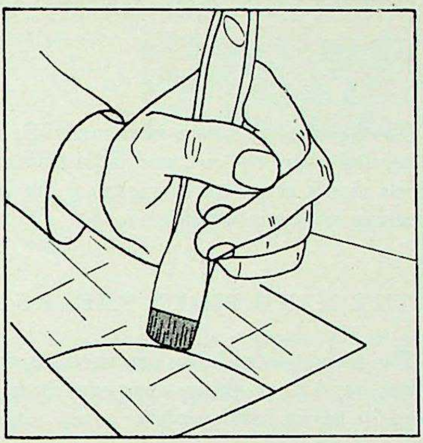


Fig. 69 Round chisel working a round edge

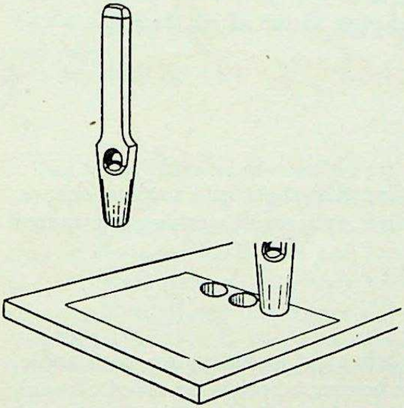


Fig. 70 Hollow chisel punching a hole. The use of the hollow chisel is usually confined to making holes in leather, rubber, pressboard etc.

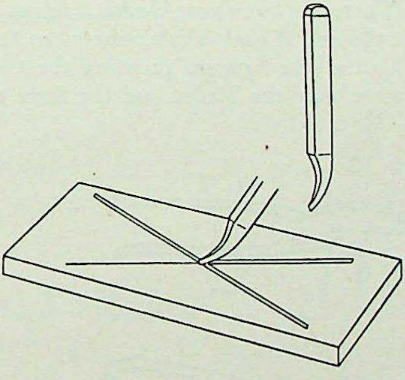


Fig. 71 Grooving chisel cutting out grooves

To prevent accidents in chiselling observe the following: Before using the chisel, make sure that

(1) the hammer is fixed firmly in the handle,
(2) both hammer face and chisel head are free from oil or grease,
(3) the chisel head is free from burrs,
(4) hammer face and chisel head are correctly rounded.

When burrs have formed on the chisel head it is possible that the chisel is not hit in the right direction. Besides, splinters chipped off the burr may injure the worker. With plane head surfaces, the hammer glances off easily or the chisel may slip away.

D. CUTTING-OFF BY MEANS OF THE HAND PLATE SHEARS

The hand plate shears part materials in such a way that only little material is wasted along the cut, and little finishing work will be necessary. Only those sheets should be parted by means of the hand plate shears whose thickness allows shearing with one hand.

I. THE HAND PLATE SHEARS

The hand plate shears are used for cutting thin sheet into various shapes. If the hand plate shears are properly handled, only small working allowances need be taken into account.

1. Design of hand plate shears

There are two shear blades, each of which has got an extension, the handle. At the end of each blade, where the handle begins, a bore is provided through which a screw passes pivoting the two parts of the shears. The handles are longer than the blades and the force to be applied is thus reduced.

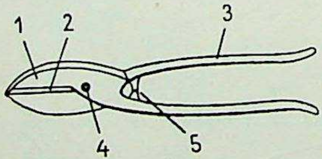


Fig. 72 Hand plate shears
1 = Shear-blade
2 = Cutting edge
3 = Handle
4 = Screw
5 = Stop for limiting the stroke

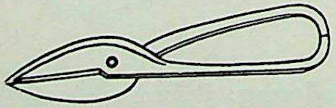


Fig. 73 Hand plate shears with a wrong type of stop for stroke limitation; this device frequently leads to bruising of the hand

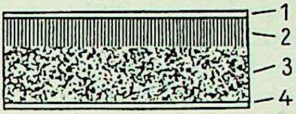
2. The operation of the hand plate shears

While in the case of the chisel one wedge penetrates the material, the plate shears operate with two wedges which move towards the material and part it.

The shearing process can be described as follows:

First the cutting edges of both blades notch the material, and then the upper cutting edge penetrates further into the material parting it with a clean cut edge until the material is torn apart up to where it was notched by the lower cutting edge.

Fig. 74 The cutting section of a shorn metal sheet



1 = The notch made by the upper cutting edge
2 = Smoothly cut part
3 = Torn face
4 = The notch made by the lower cutting edge

The hand plate shears will function properly if there is a clearance or gap between the cutting edges; this clearance is the distance separating the two blades as they pass over each other edge to edge. It depends upon the thickness of the sheet to be cut and is usually about 0.02 mm. If the two blades were to slide past one another with friction, then the cutting edges would soon be blunted and the material to be cut would be upset.

If this clearance is too large, the material is bent (when the sheet is thin), or it will be cut badly and with considerable waste.

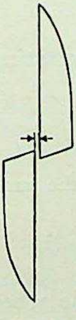


Fig. 75 Clearance between the blades

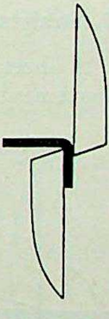


Fig. 76 Material is bent, owing to excessive clearance between the blades

II. WORKING WITH THE HAND PLATE SHEARS

When working with the hand plate shears, care should be taken that the material is held and slightly raised with your left hand, while your right hand guides the shears in cutting. Furthermore, take care to apply the shears properly when you start cutting. If you start cutting with the jaw fully opened, the blades will not attack the material immediately with their closing movement, but will push it forward. Not until an opening angle of about 15° is reached, the shear-blades start notching the material on both sides. If the opening angle of the jaw is too great, the shears may deviate from the desired cutting direction while the material is pushed forward, and faulty cuts may result. Straight cuts (1) and curved cuts (2) may be carried out by means of the hand plate shears.

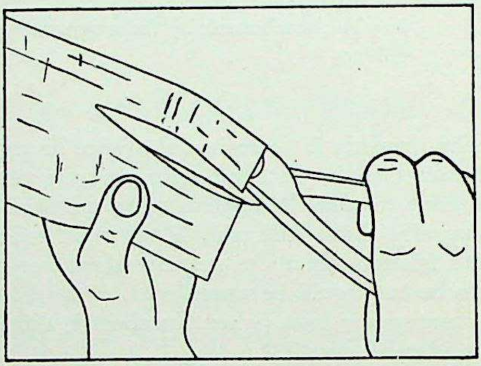


Fig. 77 Cutting by means of the hand plate shears

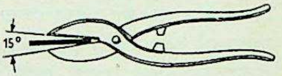


Fig. 78 Hand plate shears with correct opening angle when starting cutting

1. Straight cuts

A sheet held merely by the hand plate shears would execute a rotating movement during cutting and might thus be a cause for accidents.

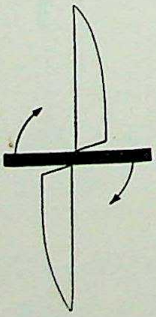


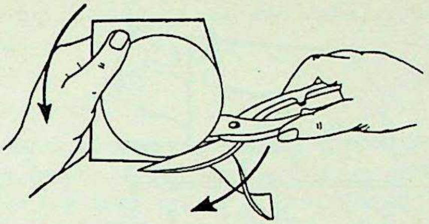
Fig. 79 Rotary movement of a sheet only held by the hand plate shears

Thus, when making straight cuts (for example when shearing metal strips from sheet) the sheet must be pressed against the bench with one hand. During cutting, the shears should not be fully closed, but re-opened shortly before the end of the closing movement, slightly lifted, and pushed further forward.

2. Making curved cuts

When making curved cuts, the sheet must be held down and guided at the same time. No matter whether the cut to be made is a full circle or only a slight curve, the shears should always be allowed to advance clockwise while the sheet is guided in the opposite direction.

Fig. 80 Making a circular cut



III. SURVEY OF THE VARIOUS TYPES OF SHEARS AND THEIR USE

Fig. 81 Plate shears are used for shearing off long strips of sheet

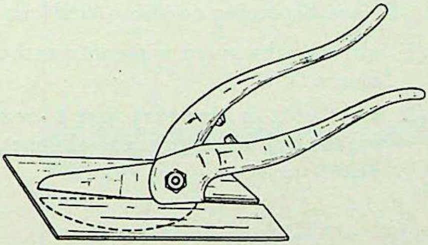
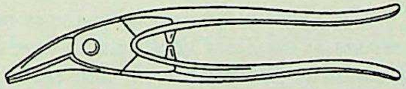


Fig. 82 Hole-cutting shears, are used to advantage where curvatures of small radii have to be cut

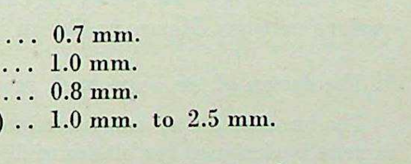


Shears of this type, when operated with one hand, are capable of cutting sheet of the following gauge:

Steel	0.7 mm.
Copper	1.0 mm.
Brass	0.8 mm.
Aluminium (according to hardness)	1.0 mm. to 2.5 mm.

Thicker sheet is frequently cut with the aid of the following shears:

Fig. 83 Bench shears. The lower end is clamped in a vice. These shears are more stable than the customary hand plate shears and are equipped with longer lever arms (handles)



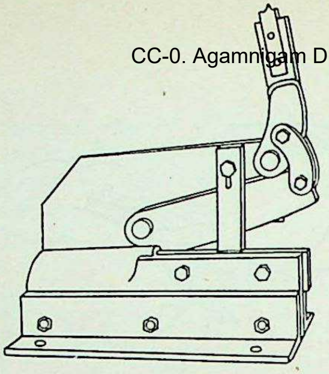


Fig. 84 Mounted shears. These are equipped with a device for holding the sheet down so that it only needs to be guided; the upper blade is curved in such a way that the opening angle is always 15°, irrespective of the blade position.

To prevent accidents when cutting by means of the hand plate shears observe the following:

Before beginning to shear, find out

(1) whether the given material can be cut by means of a pair of hand plate shears,

(2) whether it is necessary first to remove the burr from the material, or to protect the hand gripping the metal by a piece of leather.

E. CUTTING BY MEANS OF THE HAND HACK SAW

The metal at the cutting point is reduced to chips when material is parted by means of the hand hack saw. A neat cut face is obtained requiring only a small amount of finishing work, and only little material is wasted.

I. THE HAND HACK SAW

The hand hack saw allows the cutting of materials of various thickness and various sections. Moreover, it can be used for the slitting of materials.

1. The design of the hand hack saw

The hand hack saw consists of the saw frame and the saw blade. The frame is usually designed for blades of 300 mm. in length.

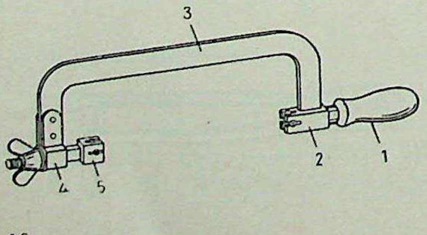


Fig. 85 Hand hack saw
1 = Handle
2 = Clamp at the handle
3 = Saw frame
4 = Guide
5 = Tightening clamp with thumb screw

The thumb screw moves the tightening clamp so that the saw blade between the two clamps is properly tensioned.

2. Action of the hand hack saw

The operation of the hand hack saw is governed by wedges of particular shape, arranged one behind the other on the blade. These wedges are called *saw teeth*. According to the number of saw teeth over a given length of the saw blade, the saw may have a coarse, medium or fine *tooth spacing*. The saw teeth attack the material and remove small chips, thus penetrating deeper and deeper into the material.

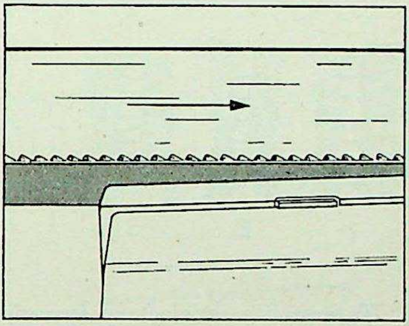


Fig. 86 The formation of chips during sawing

The chips are discharged through the *chip space*. The saw teeth must be capable, either due to a particular shape or a particular position, to penetrate the material in such a way that the saw is cutting freely, that is to say, the saw blade must not be allowed to stick in the cut gap during the cutting operation.

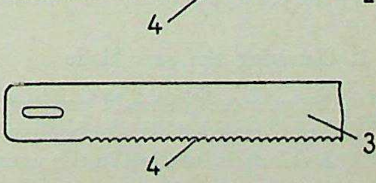


Fig. 87 Tooth spacings

1 = Coarse-tooth saw, 14 to 16 teeth over a length of 25 mm.
2 = Medium-tooth saw, 22 teeth over a length of 25 mm.
3 = Fine-tooth saw, 32 teeth over a length of 25 mm.
4 = Chip space

The examples of tooth spacings shown in Fig. 87 refer to *single-edged* saw blades. There are also *double-edged* saw blades; the latter are more economical than single-edged saw blades, but in certain positions of the saw blade in relation to the frame (see Fig. 92) the risk of accidents is increased.

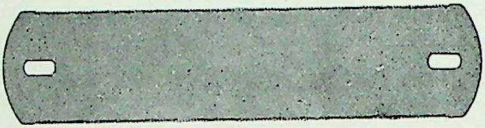


Fig. 88 Double-edged saw blade

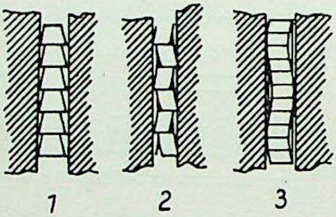


Fig. 89 Freely cutting saw blades
1 = with compressed teeth
2 = with crossed teeth
3 = with corrugated teeth

To ensure a satisfactory operation of the hand hack saw, the saw blade should be chosen in accordance with the material to be cut. Generally, soft metals, plastic and synthetic materials are being cut by coarse-tooth saws; tool steel, medium-hard steel, hard light alloys, copper alloys, and thicker sections or tubes are cut by medium-tooth saws; materials of small thickness (for example thin-walled tubes) are cut by fine-tooth saws.

II. WORKING WITH THE HAND HACK SAW

Working with the hand hack saw requires some experience if a clean cut is to be achieved, particularly when thick work pieces are to be parted. It is the rule, that the saw should be guided to and fro over the entire blade length and should execute a slightly rocking movement. We shall now deal with (1) the clamping of the saw blade and (2) the handling of the saw.

1. Clamping the saw blade

The saw teeth should penetrate the material while the hand hack saw is pushed forward. This is only possible if the teeth point in the pushing direction. If the blade is inserted in the wrong way, chips are removed during the return stroke. In this way, the cut will not be clean because the saw cannot be handled with the necessary feel.

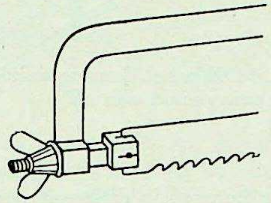


Fig. 90 Correctly clamped saw blade, its teeth pointing in the pushing direction

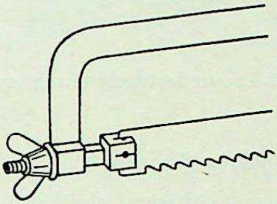


Fig. 91 Wrongly clamped saw blade

Different shapes of work pieces, in conjunction with the cut to be made, will often require specific positions of the saw blade to the saw frame. In standard hand hack saws, the clamp at the handle and the tightening clamp are slotted crosswise and thus offer four possibilities of clamping the saw blade.

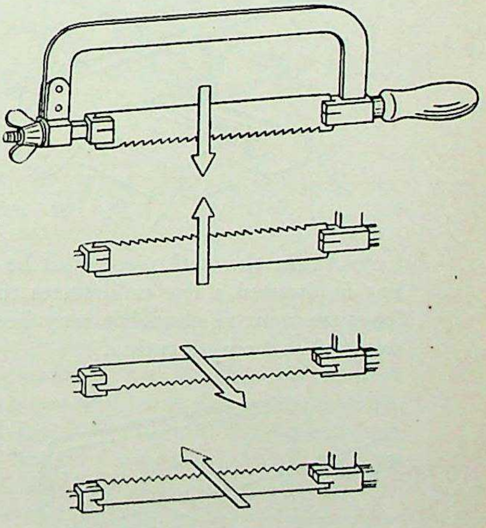


Fig. 92 Positions of the saw blade relative to the frame

When the saw blade is fastened in the clamps, care must be taken that the nails, rivets or hooks used should not project over the clamp with their ends, since this might cause accidents.

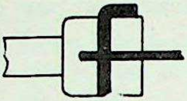


Fig. 93 Proper fastening of the saw blade

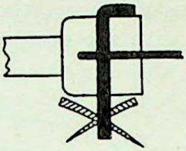


Fig. 94 Wrong! Causing accidents when the saw should slip off

2. Handling the saw

In practical work, the hand hack saw can be used in different ways. Hereunder we shall deal with *chucking the work piece*, *starting the cut*, *sawing tubes*, and *sawing shaped work pieces.*

Chucking the work piece

The work piece must be tightly chucked in the vice. Resiliently chucked work pieces do not allow a clean cut to be made and may cause the hand hack saw to slip off.

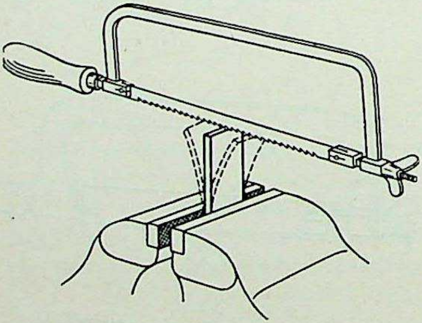


Fig. 95 Wrong! Resiliently chucked work piece

As a rule, the work piece must be chucked in such a way that the marking line is situated a few millimetres to the left of the vice jaws. If the cut is long, frequent re-chucking may become necessary in order to prevent the work piece from vibrating.

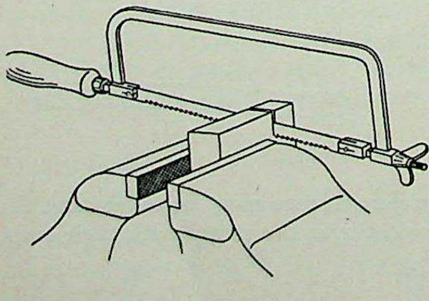


Fig. 96 Correct chucking, the marking line is at the left-hand side of the vice jaws

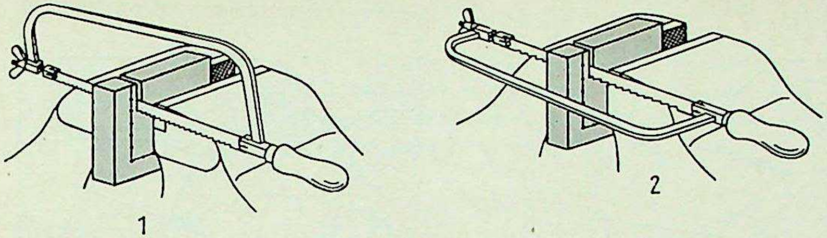


Fig. 97 Proper handling of the saw in a long cut
1 = Continue sawing until the bow touches the work piece 2 = then re-chuck the saw blade

In the case of sheets to be cut by sawing, long cuts are made with the aid of chucking squares; sawing along the vice is not consistent with good workmanship and will rapidly wear down the saw blade.

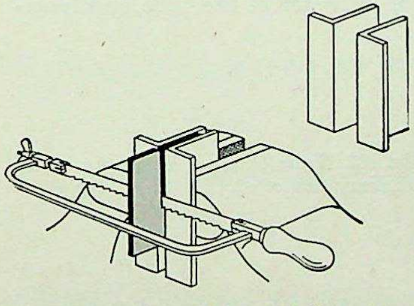


Fig. 98 Chucking with the aid of chucking squares

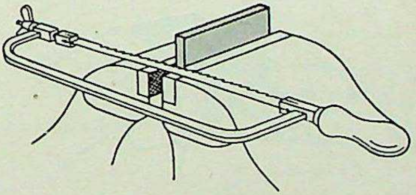


Fig. 99 Wrong! Do not saw along the vice jaw!

Starting the cut

The saw must be guided with particular care as long as the saw blade is still sliding in a saw kerf not yet sufficiently deep. If a saw kerf is not yet available when sawing is started, the saw tends to deviate from the desired direction. At this initial stage, wrong cuts or ugly scratches may originate to the left or to the right of the desired kerf. Clean starting cuts can be achieved by first filing a notch close to the marking line (at a distance of about 0.5 mm. therefrom) on the side of the piece which will fall off, using a triangular file to this end. Then the saw will be able to enter the material with some guidance. Further, be sure to begin sawing with short strokes and to apply the saw in a position somewhat inclined to the work piece, so that only small chips are removed. The proper way to begin sawing is to start from the rear edge of the work piece.

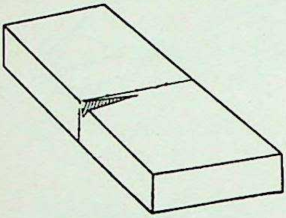


Fig. 100 Filed notch close to the marking line

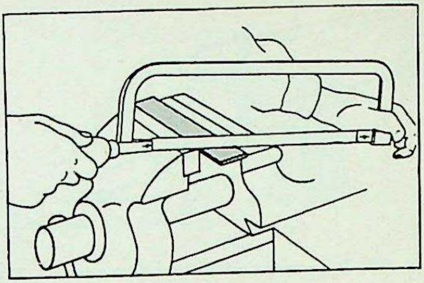


Fig. 101 Start sawing with the saw at the proper angle!

The sawing of tubes

Tubes which are easily deformed by vice pressure should be chucked by means of an auxiliary device. This consists of a wooden block being provided with a bore corresponding to the external diameter of the tube and longitudinally cut into two halves.

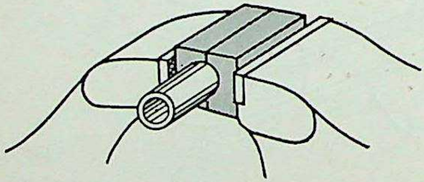


Fig. 102 Tube chucked by means of an auxiliary device

Tubes are never sawn in one go! The teeth would catch at the inner tube wall so that the saw could but inaccurately be guided while teeth would break. The procedure of sawing a tube is as follows: First file a notch and then saw into the tube down to a point near the inner wall; then turn the tube forwardly to such an extent that the saw will still be guided by the saw kerf. Then resume sawing and again cut to a point shortly before the inner wall is reached, then turn the tube through an appropriate angle and repeat this procedure, until the tube is divided.

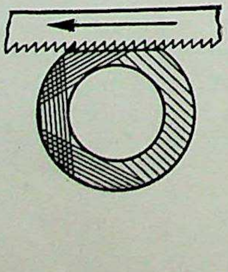


Fig. 103 Cutting faces made when sawing a tube

The sawing of sections

Shaped work pieces such as U-sections, T-sections or TT-sections are not sawn through in one go. It is necessary to mark the cut to be made on all sides of the work piece because the work piece must be sawn from several sides and it will be absolutely necessary to control the cut.

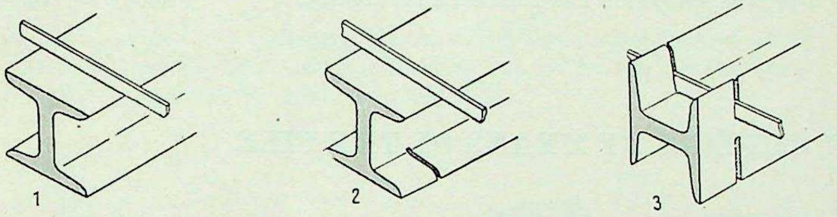


Fig. 104 Sawing a TT-section

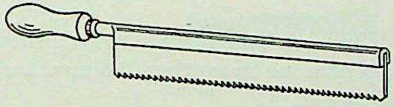
1 = Sawing through one traverse

2 = Sawing through the other traverse

3 = Sawing through the stem

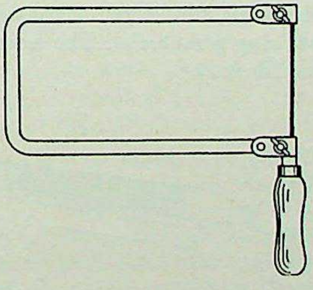
III. SURVEY OF TYPES OF SAWS AND THEIR USE

Fig. 105 Slitting saw



This saw is light and can easily be handled. It is used to cut screw slots and guide slots.

Fig. 106 Fret saw



As this saw is handled with only one hand, the saw-blade must be strained so as to be "under tension". Thus, the saw can easily be guided when exerting force in cutting. The great distance between blade and back of the saw frame enables different patterns and holes to be cut out of thin material.

To prevent accidents when sawing observe the following hints: Before beginning to saw, make sure that

(1) the work piece has been clamped tight,
(2) the cut is at the left-hand side of the vice,
(3) hooks or rivets do not project over the straining clamps,
(4) the saw-blade has been strained tightly.

F. CUTTING BY MEANS OF THE FILE

Only a small quantity of material is removed when a file is used for cutting. Filing is usually an after-treatment. It serves to remove the burr from cuts and clean the face of the cuts, and to finish the final shape of a work piece; frequently the desired surface quality can be obtained by filing.

I. THE FILE

The work pieces are rough-finished by means of other cutting tools so that in general no more than 0.6 mm. tooling allowance is left for filing.

1. Design of the file

The usual files consist of the blade and the tang. The blade has got teeth cut or milled into it; the tang serves for fastening the handle.

Above all, the length of the blade is of particular importance to the process of working a material. The nominal length of a file refers only to the length of the blade.

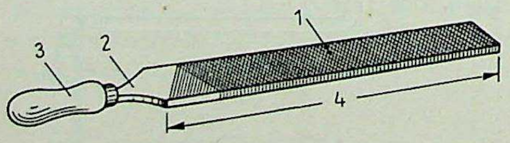


Fig. 107 File
1 = Blade
2 = Tang
3 = Handle
4 = Nominal length

Different kinds of files are required to tool differently shaped work pieces. Several file types differ from the usual design. For instance, needle files, which normally have only a small nominal length, taper to a round rod and have no pointed tang.

The blade of the file is hardened whereas the tang is not hardened. The hardened tang would easily break off and thus become a source of accidents. Files with a tang must never be used without handle because the point of the tang could penetrate into your hand or artery when it should inadvertently slip off.

2. Action of a file

As a rule, cut files give a *scraping* action, milled files a *cutting* action. Thus, to obtain best results, hard metals should in general be worked by means of a cut file, soft metals by means of a milled file.

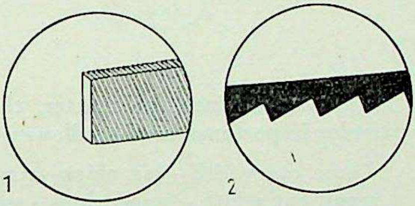


Fig. 108 Cut file

1 = Single-cut teeth arrangement without chip breaking flutes
2 = Cut file teeth, scraping action

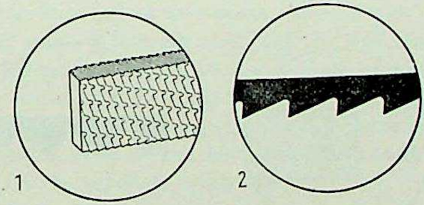


Fig. 109 Milled file

1 = Single-cut teeth arrangement with chip breaking flutes
2 = Milled file teeth, cutting action

Single-cut files are used if a very smooth surface is to be obtained. It is, however, very hard to get these files penetrating into the material. This is why chip breaking flutes are cut into the file to divide the cutting edges, which thus permit to obtain the same surface quality of the work piece with less exertion of force.

The greater part of the usual files are double-cut files.

The distance between file cuts is called cut width; the cuts are arranged in a certain angle aslant to the imaginary file axis; the distance between the cuts in the direction of the imaginary file axis is called cut spacing.

A double-cut file is obtained when a second cut, the over-cut, is superimposed upon the first cut, the so-called under-cut, at an angle different from that of the under-cut. The angles must be selected in such a way that the file is enabled to perform the so-called "drawing cut".

The over-cut produces many small teeth which satisfactorily attack the material. However, the surface of the work pieces shows severer score marks when worked with a double-cut file than when worked with a single-cut file.

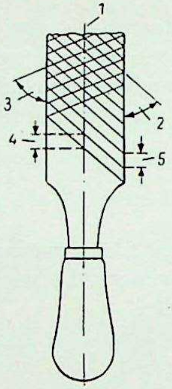


Fig. 110 Double-cut file

1 = File axis
2 = Angle of under-cut
3 = Angle of over-cut
4 = Cut width
5 = Cut spacing

To go further into the matter, the cut width of double-cut files is of particular importance as the following interrelations show:

Large cut width – big chips – rough surface,
small cut width – small chips – smooth surface.

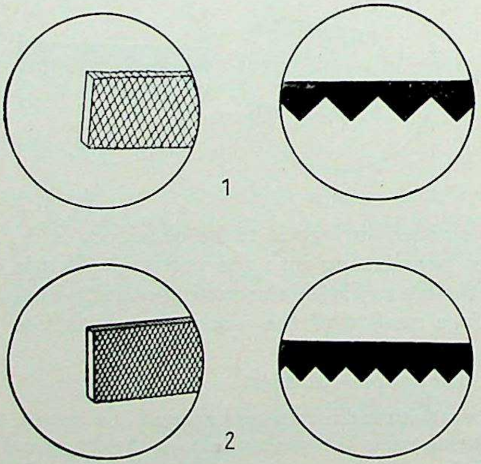


Fig. 111 Cut width of a rough file and a smooth cut file

1 = Rough file — large cut width
2 = Smooth cut file — small cut width

Selecting a file by its cut width is dependent on (1) the amount of the tooling allowance and (2) the required surface quality. First the work piece is rough-filed by means of files with large cut widths, leaving only about 0.2 mm. of the tooling allowance on the surface which is then smoothed and, if required, fine-finished by means of files with smaller cut widths.

The surface quality obtained is dependent on the file used. The technical drawing generally states the desired surface quality. In the same way as in the case of checking by touch, the surface qualities are distinguishable into rough, fine, and very fine finish. Standardized symbols for the designation of surface finish are laid down in the technical drawing.

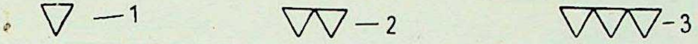


Fig. 112 Symbols for the designation of surface finish
1 = Rough finish; 2 = Fine finish; 3 = Very fine finish

II. WORKING WITH THE FILE

Working with the file requires some skill. The necessary abilities to finish a work piece according to the technical drawing at minimum expenditure of time are achieved by repeated training only. When carrying out the different operations with a file, we find the following factors to be of importance: (1) the height of the vice, (2) the position of your feet, (3) the handling of the file, (4) the chucking of the work by means of protecting jaws, (5) the chucking of the work by means of the saw sharpening vice, (6) the mounting of the work on the filing board, and (7) the filing on the wooden stock block.

1. The height of the vice

Generally, the work piece to be filed is chucked in the vice. The height of the vice is of importance to the proper handling of the file because it may influence the labour efficiency of the filing worker. The following rule has been established: The height of the vice is correct when the worker in upright position can place his fist under the chin with his elbow resting on the vice jaws.

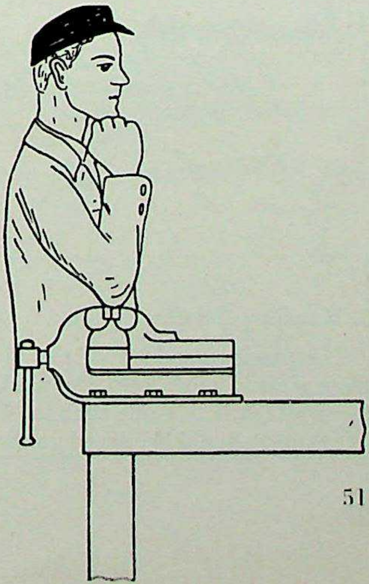


Fig. 113 Correct height of vice

The worker will soon become tired if he neglects this rule. Further, he will not be in a position to watch the work piece well during filing.

2. The position of your feet

There is an interrelation between the angles of the over-cut and the under-cut of the files and the position of the worker at the vice. The worker should place his left foot in the direction of the file stroke. His right foot should be placed at an angle of 90° in relation to his left foot.

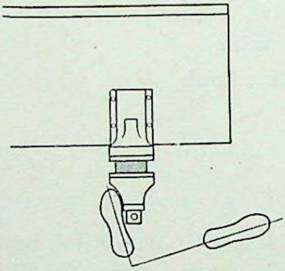


Fig. 114 Position of the feet when the file stroke is from the left to the right

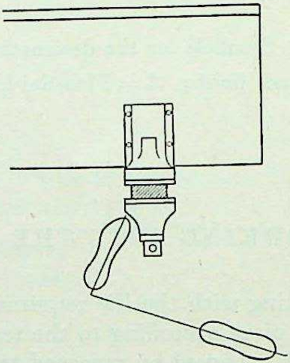


Fig. 115 Position of the feet when the file stroke is from the right to the left

A plane surface can be produced only, if the file strokes run alternately from the left to the right and from the right to the left. This way of filing is called "cross stroke filing".

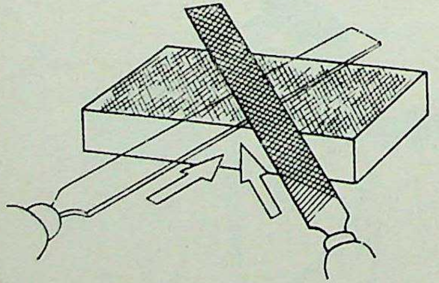


Fig. 116 Cross stroke filing

3. Handling the file

The proper handling of the file is an important condition of satisfactory filing work. In principle, the worker should grip the file handle with his right hand, which is to guide the file. When working with large files, the ball of the left thumb should be placed on the end of the file blade which is clasped by the fingers. The left hand exerts an increasing pressure on the file in forward motion. The pressure is removed in return motion. However, the motion of the file must be adapted to the shape of the surface in question, whether the file is moved forward or back.

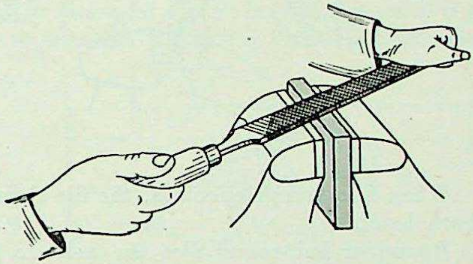


Fig. 117 Proper handling of the file

Together, the two motions should be performed in a somewhat rocking way as is the case with sawing by means of the hand hack saw. Generally, the worker should continue to file in one direction until this file stroke leaves a clearly visible mark on the work piece surface; the direction of filing should then be changed. The worker should also judge by this second file stroke to what extent the desired shape or surface quality of the work piece has been achieved.

The right hand is to guide the stroke also when working with medium-size files, while thumb and forefinger of the left hand exert the necessary pressure.

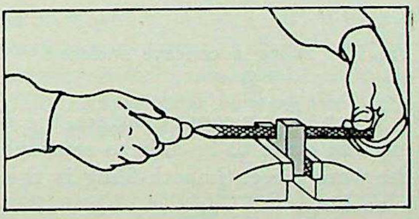


Fig. 118 Proper handling of a medium-size file

When working with small files, the file should be pressed against the work piece with several fingers of the left hand.

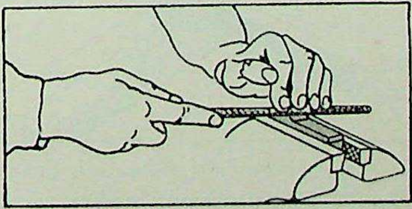


Fig. 119 Proper handling of a small file

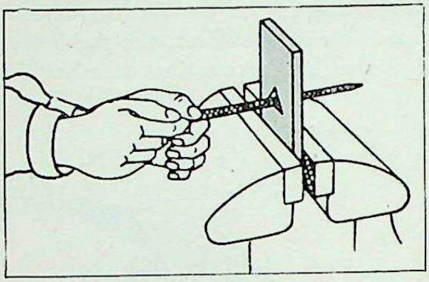
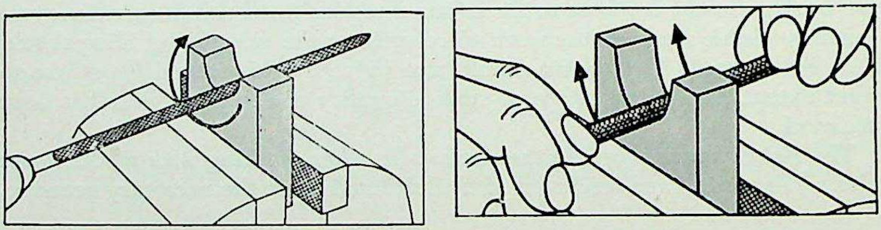


Fig. 120 Handling the file when filing small openings

When filing small openings, the file should be gripped at the handle with both hands.

Round or half-round files are used to file concave surfaces. In forward motion, it is necessary to turn the file slightly sideward in order to obtain a uniform roundness.

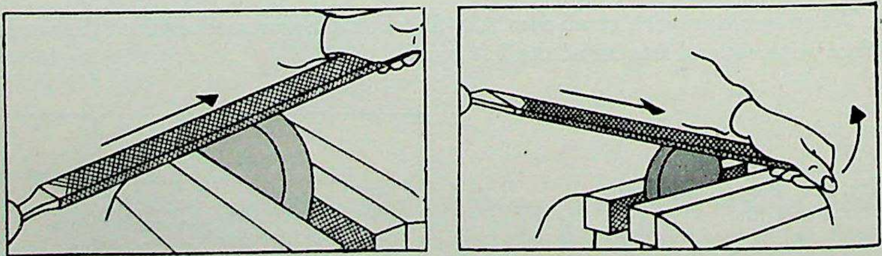


1

2

Fig. 121 Filing a concave surface 1 = Rough-filing; 2 = Smooth-filing

When filing a convex surface, the direction of rough-filing is across the work piece in order to be able to continuously watch the marking at the front of the work piece. Smooth-filing is then in longitudinal direction while the file is rocking.



1

2

Fig. 122 Filing a convex surface 1 = Rough-filing; 2 = Smooth-filing

4. Chucking the work piece by means of protecting jaws

The general instructions about chucking work pieces in chiselling and sawing apply also to filing. The work piece must not be allowed to vibrate while it is being worked. When filing, care should also be taken that the surface of the work piece will not be damaged by the hardened jaws of the vice. That is, why in many cases a wooden vice clamp dog is inserted between vice jaws and work piece.

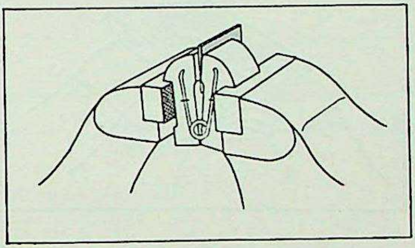


Fig. 123 Chucking a work piece by means of a wooden vice clamp dog

In addition to protecting jaws of wood, protecting jaws of lead can be used for chucking the work piece; the leaden jaws are required if, for example, threaded bolts are to be filed. Protecting jaws of lead will not damage the thread.

5. Chucking the work piece by means of the saw sharpening vice

In metal working, it is frequently necessary to chamfer the edges of the work piece. The chamfer has in principle an angle of 45° in relation to the plane of the work piece. The saw sharpening vice, clamped in the vice in the same way as the vice clamp dog, has a throat which is arranged in an angle of 45° in relation to the vertical axis. This arrangement enables the work piece to be chucked in such a way that the desired angle is obtained with a horizontal file stroke.

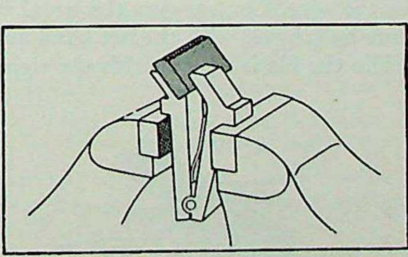


Fig. 124 Chucking a work piece by means of the saw sharpening vice

6. Mounting the work piece on the filing board

The surface of thin sheet-metal cannot be filed properly without appropriate auxiliary devices. The surface of a thin sheet-metal can be finished in the desired way by means of the filing board. The filing board consists of a longitudinal member to be clamped in the vice and a board which serves for mounting the sheet-metal to be filed. It may become necessary to change the position of the work piece several times in accordance with the desired surface quality.

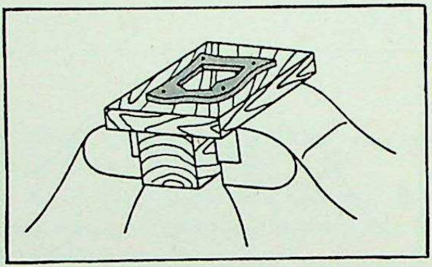


Fig. 125 Mounting a thin sheet-metal on the filing board

The surface is given the final touch by filing transversely to the longitudinal axis of a file suitable for this work.

A dead-smooth surface can also be achieved by "draw-filing" the surface by means of chalk and oil and a dead-smooth file which has frequently been used. If a new file is used for draw-filing, the formation of scores cannot be avoided despite the application of chalk and oil to the surface.

7. Filing on the wooden stock block

If round material with a diameter appropriate to the work in question is not available, then cylindrical filing may become necessary. In this case the wooden stock block is used as an auxiliary device. This is a scantling with a round recess adapted to the work piece to be filed. This block must be clamped in the vice. Contrary to the usual handling of the file, the round material is to be gripped with the left hand and turned towards the body of the worker while the file is moved with the right hand pressing it down forwardly.

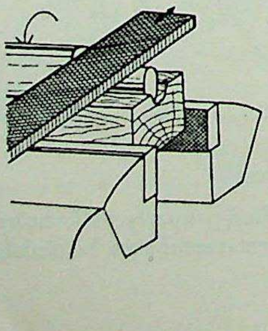
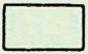
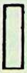
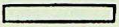
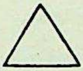
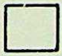
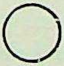
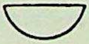
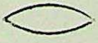
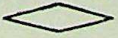


Fig. 126 Filing on the wooden stock block

III. SURVEY OF FILE TYPES AND THEIR CUT WIDTHS

The following file types are most frequently used for the different shaping work in question:

Type of file	Section	Applications
Square file		Working large areas, roughing, rough surfaces
Hand file		Coarse file, rough work, rough surfaces
Flat file		Plane surfaces, rough- and smooth-filing
Triangular file		Filing corners, triangular cuts
Rectangular file		Rectangular corners, rectangular cuts
Round file		Concave surfaces, round cuts
Half-round file		Round cuts, concave surfaces, the flat side of the file is used for plane surfaces
Crossing file		Flat-round cuts, concave surfaces, curves, radii
Lozenge file		Narrow cuts, angles below 45°

In conjunction with the amount of tooling allowance and the desired surface quality, the files are classified by their cut widths. Files are available in different nominal lengths.

Number of file cut	Type designation of file	Usual nominal lengths						
		100	160	200	250	315	375	450
		Number of cuts over a length of 1 cm.						
0	Coarse file	10	8	7.1	6.3	5.6	5	4.5
1	Bastard file	14	11.2	10	9	8	7.1	6.3
2	Rough-finish file	22.4	18	16	14	12.5	11.2	10
3	Smooth cut file	31.5	25	22.4	20	18	16	14
4	Dead-smooth file	45	35.5	31.5	28	25	—	—
5	Super-smooth file	63	50	45	40	—	—	—

To prevent accidents in filing, observe the following hints.
Before beginning to file make sure that

(1) the file handle is firmly attached to the tang,
(2) the file is clean,
(3) the work piece is tightly chucked.

G. CUTTING BY MEANS OF THE DRILL

When using a drill for cutting, circular holes are cut into the material; they may pass through the work piece (through drill holes) or reach down to a certain depth only (bottom drill holes). Cutting by means of the drill is an economical working method and requires only little re-finishing work.

I. THE SPIRAL DRILL

The spiral drill is most frequently used for drilling metals.

1. Design of the spiral drill

Fig. 127 shows the design of a spiral drill. The main parts of the spiral drill are the cutting face length, the neck, and the shank. Small spiral drills often have no neck milled into them, and the shaft is the direct continuation of the cutting face length. The end of the cutting face length is formed by two cutting lips arranged at a specific angle to each other, the so-called lip angle. Two helical grooves are milled into the cutting face length in order to provide for a satisfactory discharge of the chips. The helical grooves are relief-ground in the sense of rotation of the drill and are thus given a heel.

The choice of the most favourable lip angle for the material in question is dependent on the kind of the material to be drilled. It has been found out that, for example, the following lip angles give the best results when applied to the following materials:

Lip angle	Material
130° to 140°	Aluminium alloys
116° to 118°	Steel, grey cast iron
80° to 90°	Slate, hard paper
30° to 40°	Hard rubber

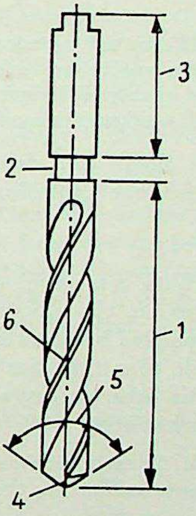


Fig. 127 Spiral drill

1 = Cutting face length
2 = Neck
3 = Shank
4 = Cutting lip
5 = Lip angle
6 = Heel

2. Action of the spiral drill

The cutting lips are uniformly removing chips from the work piece while the spiral drill must penetrate deeper and deeper into the work piece. This means that two different motions are necessary, namely, a rotating motion round the longitudinal axis of the drill and an advancing motion in the direction of its longitudinal axis towards the work piece. These two motions are called cutting speed and feed.

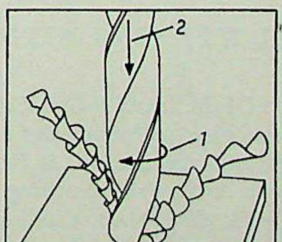


Fig. 128 Motions involved in drilling

1 = Cutting speed
2 = Feed

Cutting speed

If we marked a point on a cutting edge of the spiral drill, this point would cover a certain distance with the spiral drill making one full revolution. When, for example, this spiral drill makes 100 rotations per minute, then the point would cover 100 times the aforesaid distance. When we consider the drilling operation from this angle, we find that distance and time are related to each other:

$$\text{Cutting speed} = \frac{\text{Cutting distance}}{\text{Cutting time}}$$

The cutting distance is indicated in metres, the cutting time in minutes. The value of the cutting speed is dependent on the kind of material to be drilled, and the diameter and quality of the spiral drill used. In general practice, only the diameter of the spiral drill is taken into consideration, and the following relations are found to be true:

Small drill diameter – high speed
Large drill diameter – low speed.

Feed

With most drilling machines and drilling tools, which will be discussed later on, the advancing motion of the spiral drill is caused by the energy expended by the worker. If much energy is expended to advance the rotating drill, then the spiral drill will penetrate quickly into the work piece, whereas with little energy expended the spiral drill will penetrate slowly into the work piece.

If, for example, the spiral drill makes one rotation while penetrating into the material by one millimetre, then the feed is

$$1\,\frac{\text{mm. (millimetre)}}{\text{R (rotations)}}$$

The greater the feed, the quicker the spiral drill should penetrate into the material. However, this holds true within certain limits only. There is an interrelation between cutting speed and feed, and the feed must be adapted to the cutting speed.

II. WORKING WITH THE PILLAR DRILLING MACHINE

Of the many types of drilling machines and drilling tools, the pillar drilling machine is frequently used in workshops. When working with the pillar drilling machine, it is indispensable to know the design of the machine, the use of the drill chucking devices and of the different holding fixtures for the work piece. On the following pages we shall deal with: (1) design of the pillar drilling machine, (2) chucking devices for the drills, (3) driving in and driving out the drill chuck, (4) holding the work by means of the fixing screw, (5) mounting by means of a gripping plate and spacers, (6) mounting by means of a gripping plate and V-block, (7) mounting by means of pivoted vices, and (8) cutting coolants and lubricants.

1. Design of the pillar drilling machine

Fig. 129 shows the design of a pillar drilling machine. A pillar mounted on a base plate carries the bracket of the drilling machine table and the upper part. The drilling machine table is pivoted in a bracket; the bracket is vertically adjustable by means of a rack arranged at the pillar. In addition, the bracket can usually be turned towards the left and the right together with the drilling machine table. Crossing T-slots are almost always cut in the drilling machine table. These slots are designed to accomodate the screw heads of the fixing screws.

The upper part of the pillar drilling machine consists of the drill head, the drill spindle, and the gear case.

The drill spindle is running in bearings inside the gear case and the drill head. The rotating motion is imparted to the drill spindle from the gear case, and the advancing motion (feed) towards the work piece from the spindle head. A toothed wheel is arranged in the spindle head which has a lever that can be handled from the outside. The toothed wheel meshes with a drill spindle sleeve so that the drill spindle can be mooved in the direction of its axis by means of this lever.

(However, there are also pillar drilling machines with provisions for an automatic adjustment of the feed; in this case the feed motion is imparted from the gear case.)

The gear case carries an electric motor and houses the intermediate gear. The electric motor supplies the driving power which can by means of the intermediate gear be converted into rotatory movement, mostly arranged in three different speeds.

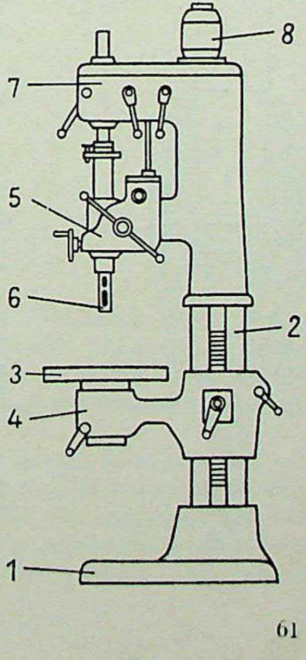


Fig. 129 Design of a pillar drilling machine

1 = Base plate
2 = Pillar
3 = Drilling machine table
4 = Bracket
5 = Drill head
6 = Drill spindle
7 = Gear case
8 = Electric motor

2. Chucking devices for the drill

The end of the drill spindle is a tube; the hole of the tube is tapered in upward direction. In addition, the drill spindle has a slot arranged on a level with the end of the tapered hole.

The tapered hole serves to hold, the slot to release the chucking device for the drill. The generally used chucking devices are the three-jaw chuck, the two-jaw chuck, and the taper sleeve.

Three-jaw chuck

Fig. 130 shows a three-jaw chuck, which normally is used for spiral drills with diameters up to 10 mm.

The upper part is a cone shank fitting into the drill spindle. The lower part consists of the chuck body, which has an external thread for the chuck collet. The inside of the chuck collet is tapered so that it can compress the three chuck jaws staggered by 120°. Pressure springs are arranged between the three chuck jaws. These springs constantly press the chuck jaws against the inner wall of the chuck collet.

When a spiral drill is put into the chuck, it will be positioned exactly in the centre of the drill spindle because of the pressure excerted by the three chuck jaws. In this way, the drill is centered, as this procedure is called.

Two-jaw chuck

Fig. 131 shows a two-jaw chuck which generally is used for spiral drills with larger diameters.

The upper part is formed by a cone shank, as is the case with the three-jaw chuck. The lower part is formed by the juck body housing two sliding chuck jaws and one chucking worm. One half of the chucking worm is provided with a left-hand thread, the other half with a right-hand thread. One end of the chucking worm is provided with a (square) guide into which a square wrench can be put. When the chucking worm is tightened by means of the square wrench, the chucking jaws move towards each other, because one jaw has a left-hand thread and the other one a right-hand thread in

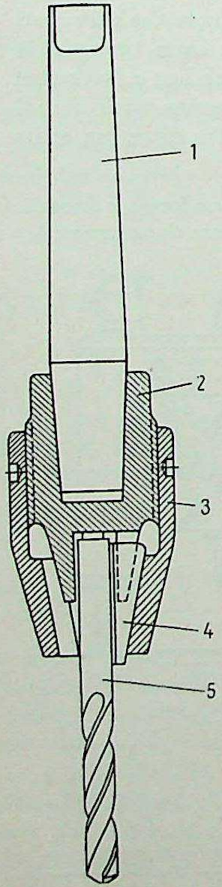


Fig. 130 Three-jaw chuck

1 = Cone shank
2 = Chuck body
3 = Chuck collet
4 = Chuck jaws
5 = Spiral drill

accordance with the thread arrangement of the chucking worm. This type of a chuck permits to fasten spiral drills very tightly.

Two-jaw chucks have, however, one disadvantage. The mass of the chuck is not uniformly distributed around the central axis. At high speeds this induces uncalled-for vibrations which cause the spiral drill to run out of centre. This may lead to the destruction of the drill when it enters the work piece.

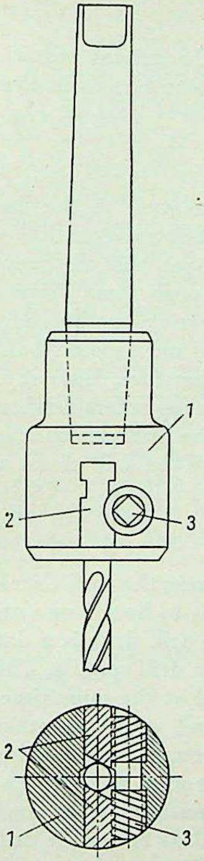


Fig. 131 Two-jaw chuck

1 = Chuck body
2 = Chuck jaws
3 = Chucking worm

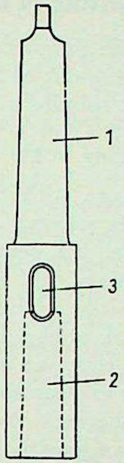


Fig. 132 Taper sleeve

1 = Cone shank
2 = Tapered hole
3 = Slot

Taper sleeve

The spiral drill described on page 58 has a cylindrical shank. Other spiral drills, in particular those with a large diameter, have a cone shank. Spiral drills with cone shanks, provided they belong to the large-diameter range, can directly be inserted into the drill spindle sleeve because cone shank and tapered hole match.

Whenever the cone shank is smaller than the tapered bore, taper sleeves must be used. The taper sleeves have a cone shank to fit into the drill spindle. This cone shank has an extension and is provided with a tapered bore for spiral drills of a certain diameter. A slot serving to release the spiral drill is provided at the end of the tapered hole, as is the case with the drill spindle.

3. Driving in and driving out the drill chuck

The following explanation also applies analogously to the driving-in and driving-out of the taper sleeves, or such spiral drills which can be put in the drill spindle without any chucking device.

Driving in the drill chuck

Even with the cutting speed and the matching feed as well as the lip angle selected correctly for the drilling operation to be performed, and the spiral drill centered properly in the drill chuck, it may happen that the bore obtained will not be clean unless the drill chuck has properly been driven into the drill spindle. Frequently, small metal chips adhering to the cone shank of the drill chuck will creep in between cone shank and tapered hole and cause an unsymmetrical position of the drill chuck. Therefore, make it a rule to clean the cone shank and tapered hole by means of a rag before driving in the drill chuck. Always introduce the cone shank of the drill chuck into the tapered hole slowly. As soon as you feel a reaction, give the drill chuck a slight tap with your palm. Never use any striking tool for driving in!

Driving out the drill chuck

Frequently, the forces of pressure involved in drilling press the drill chuck very hard against the drill spindle. When the drill chuck is to be driven out, then a drill drift or loosening wedge should be used. The drill drift is a flat slender steel wedge, which must be put into the slot of the drill spindle. The drill drift must be moved up and down, pushing it forward at the same time. As a rule, the drill drift should be handled with one hand while the other hand holds the drill chuck. If the power of your hand is not sufficient to drive the drill chuck out, a rubber or wooden hammer may be used to drive the wedge into the slot. Before using a hammer, the drilling machine table must be padded with cleaning rags and brought up to a point close below the drill chuck. A drill chuck allowed to fall on a non-padded drilling machine table may get distorted. This results in unsatisfactory drill holes.

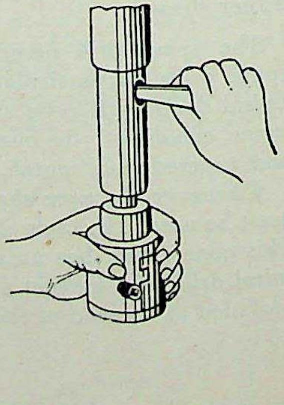


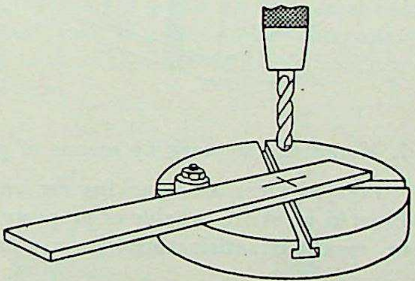
Fig. 133. Driving out the drill chuck by means of the drill drift

4. Holding the work by means of the fixing screw

As has already been described, the drilling machine table is provided with two crossing T-slots. They serve in the first place to accomodate the fixing screws in such a way that their heads are allowed to slide, but not to turn in the slots. The threaded ends of the fixing screws project from the drilling machine table and enable, in connection with nuts, the work piece to be mounted in different ways. Secondly, the slots of the drilling machine table can be adjusted in such a way that a drill emerging from a through drill hole can lower into a slot without damaging it. The drilling machine table must never be damaged by the drill, this is a rule of good workmanship! Long work pieces which project over the drilling machine table and can be held by hand, are not clamped but placed against a fixing screw. This fixing screw is fastened with its nut close to the edge of the drilling machine table, at the left-hand side of the work piece. The work piece must contact the fixing screw during drilling.

If you fail to use the fixing screw for stopping the work piece, accidents may occur because the work piece tends to follow the rotation of the drill. If, in such a case, the feed increases to a certain extent, the work piece may be snatched from the worker and injure him.

Fig. 134 Fixing screw arranged to hold the work piece

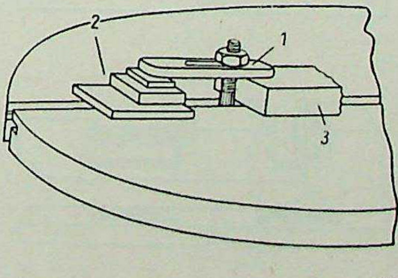


5. Mounting the work by means of gripping plate and spacer

Compact and thick work pieces are best mounted by means of gripping plate and spacers. Steel plates of a different thickness are used as spacers which can be arranged in such a way that their over-all height amounts to

Fig. 135 Mounting the work piece by means of gripping plate and spacers

1 = Gripping plate
2 = Spacers
3 = Work piece



the thickness of the work piece to be drilled. If the over-all height of the spacers used is greater or smaller than that of the work piece, the work piece cannot be fastened properly, and it may be snatched away by the drill due to its rotation.

6. Mounting the work by means of gripping plate and V-block

Cylindrical work pieces are mounted by means of a gripping plate and a V-block. The gripping plate must be long enough to be fastened by two fixing screws at both ends with the V-block and the work piece placed between them. For drilling through holes, the gauge point must be applied in such a way that the drill is allowed to run into the work piece close to the V-block.

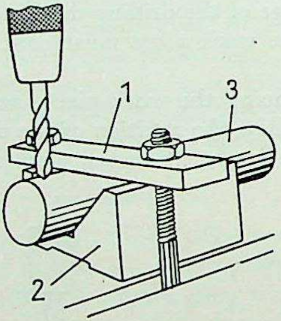


Fig. 136 Mounting the work by means of gripping plate and V-block

1 = Gripping plate
2 = V-block
3 = Work piece

7. Mounting the work by means of pivoted vices

Pivoted vices are chucking devices designed to mount small work pieces. Pivoted vices are capable of properly holding small work pieces which cannot be mounted satisfactorily by means of the above-mentioned work holding

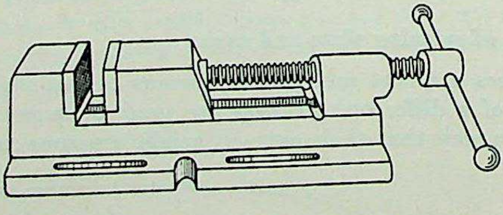


Fig. 137 Pivoted vice with parallelly arranged jaws
It serves to chuck very small, flat work pieces

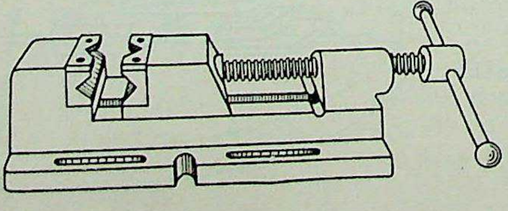


Fig. 138 Pivoted vice with V-shaped jaws
It serves to chuck cylindrical or square work pieces with small diameters

fixtures. The pivoted vice must properly contact the drilling machine table. Therefore it is fastened to the drilling machine table by means of fixing screws.

Pivoted vices are distinguished according to the design of their vice jaws into pivoted vices with parallely arranged jaws and pivoted vices with V-shaped jaws.

8. Cutting coolants and lubricants

Cutting speed and feed induce frictional heat at the drill and the work piece. The frictional heat is different depending on the kind of material being drilled. When the frictional heat increases to a certain amount it gives rise to a detrimental effect on the drill. In most cases, the drill will lose its hardness when it is exposed to excessive frictional heat. To avoid these detrimental effects when drilling steel or aluminium and their alloys, cutting coolants and lubricants are used with best results; when drilling plastic material, compressed air will be the best cooling agent.

The basic substance of the usual liquid cutting coolants and lubricants is water with soap and oil dissolved and finely distributed in it.

When a cutting coolant and lubricant is poured on the drill and the work piece during drilling, first the water will evaporate due to the frictional heat. As a result drill and work piece are cooled down. The soap and oil components of the agent will remain and form a film on the wall of the drill hole, which will reduce the frictional heat at the same time.

Sharpening spiral drills

Electrically driven grinding wheels are used to sharpen blunt spiral drills.

Spiral drills having a diameter over 10 mm. should be sharpened by means of the spiral drill sharpening machine only.

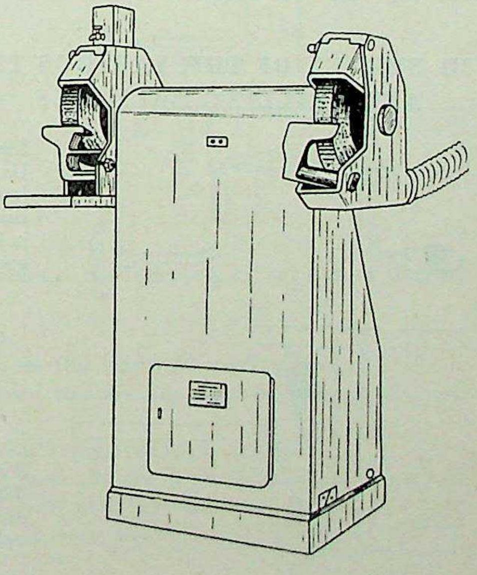


Fig. 139 Electrically driven grinding wheels

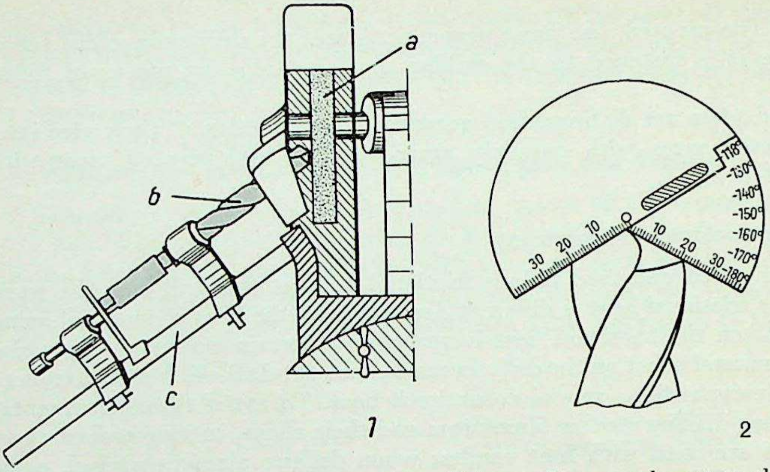


Fig. 140 Spiral drill sharpening machine. This machine can be set to the required lip angle and enables proper relief-grinding of the lands.
1 = Spiral drill sharpening machine a) Grinding wheel b) Spiral drill
2 = Gauge for testing lip angles c) Sharpening attachment

When sharpening the drill by hand, it is indispensable to repeatedly check the lip angle and the length of the cutting lips by means of the spiral drill sharpening gauge.

Cutting coolants must be used for sharpening.

Improperly sharpened spiral drills cause inaccurate drill hole diameters and the drills will break easily.

III. SURVEY OF THE VARIOUS TYPES OF DRILLING TOOLS AND DRILLING MACHINES

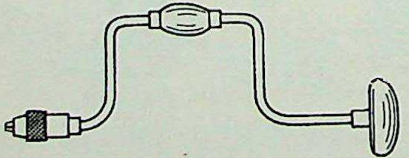


Fig. 141 Breast drill
Usually, this tool is provided with a two-jaw chuck for drills with a tapered square shank. This tool is often used for drilling individual holes at places difficult to approach, and for assembly work.

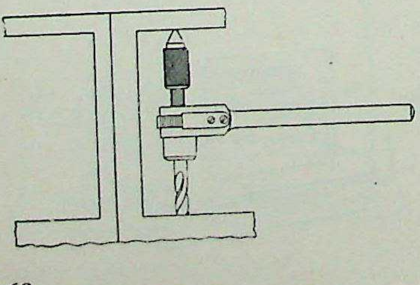


Fig. 142 Ratched drill
This tool is particularly used in steel construction where holes must be drilled in section iron which is hard to get at.

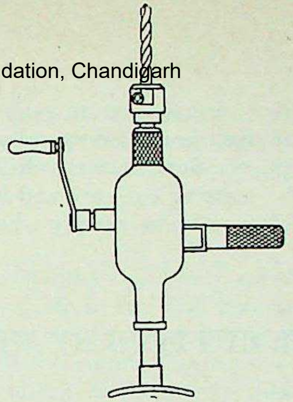


Fig. 143 Manually operated hand drill
This drilling machine is arranged for two speeds. The speeds are selected by shifting the grip and the crank handle. These tools are usually equipped with a three-jaw chuck for drills up to 10 mm. in diameter.

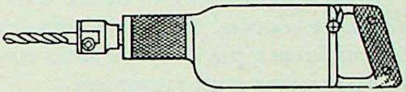


Fig. 144 Hand drill with electric drive
This drilling machine is arranged for two speeds. Generally, they are equipped with a two-jaw chuck for drills up to 25 mm. in diameter. These hand drills may also be provided with detachable breast plate and two lateral grips. There are also other designs which can be mounted on an upright and thus be operated as a bench drilling machine.

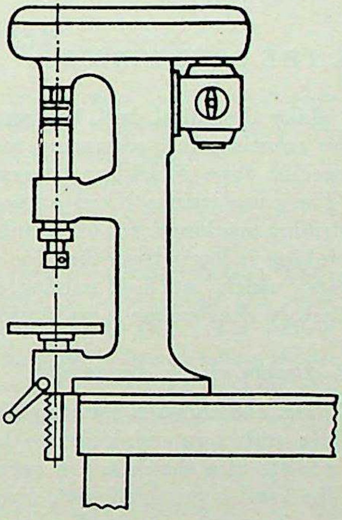


Fig. 145 Bench drilling machine
This drilling machine is designed for small work pieces and drill holes up to 6 mm. in diameter. The feed motion is effected by the drilling machine table while it is pressed upwards.

To prevent accidents in drilling observe the following hints. Before starting drilling, make sure that

(1) the work piece is firmly fixed,
(2) the fixing screw closely contacts the mounted work piece,
(3) the chips have been swept from the drilling machine table and work piece,
(4) the drill shank and the drill chuck are free from chips,
(5) a brush is readily at hand because the chips must never be wiped off with your hands or blown off with your mouth,
(6) your clothing is fitting tightly to your body,

(7) you have put on your protective cap,
(8) you are standing sufficiently away from all rotating parts,
(9) the floor near the drilling machine is dry and has not been wetted by cutting coolants and lubricants,
(10) you know exactly where the main switch of the machine is located.

H. CUTTING BY MEANS OF THE COUNTERSINK

Drill holes are further treated by means of the countersink, another tool for detaching cuttings. Thus, drill holes can be burred, chamfered, faced or enlarged. The different types of countersinks must be sharp and applied in such a way that no re-finishing work is required.

I. THE COUNTERSINK

Like the spiral drill, the countersink detaches chips from the work piece by rotating and advancing motions. Countersinking may be considered a specific type if drilling process designed to change an existing drill hole. (The countersinks listed on page 73, see paragraph III., are chucked in the drilling machine for countersinking.) Generally, the cutting speed for countersinking is lower than that for drilling. The countersinks have many cutting lips, which, at high cutting speeds, produce so many chips that a satisfactory chip escape is no longer secured.

1. Design of the countersink

Fig. 146 shows a countersink which can be used both for burring a drill hole and countersinking the head of a countersunk rivet. The countersink consists of a shank and a cylindrical head which is thicker than the shank. The head is provided with several cutting lips arranged at a specific angle in relation to the longitudinal axis of the countersink.

The angle between the cutting lips and the longitudinal axis is called angle of countersink. Usually, this angle is not of importance for burring a drill hole, whereas

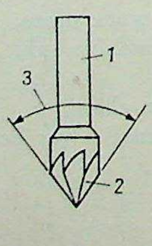


Fig. 146 Countersink

1 = Neck
2 = Head
3 = Angle of countersink

it plays an important part in cutting tapered countersinkings for countersunk rivets or countersunk screws; for example, some countersunk screws call for an angle of countersink of 20°, some countersunk rivets for an angle of countersink of 75°.

2. Action of the countersink

The countersink is a tool with several cutting lips designed to detach small cuttings from a material. The countersink has no guide in the drill hole in countersinking and thus tends to run off centre. The more cutting lips there are in a countersink, the better it will follow the wall of the bore. The countersink must always be firmly chucked in the drill chuck. Countersinks with only a few cutting lips, and multilipped countersinks operated at too high a cutting speed tend to "shatter", that is to say, they no longer will cut but tear chips from the material.

II. WORKING WITH THE COUNTERSINK

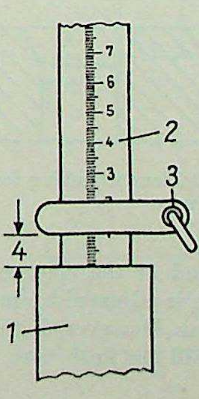
In principle, the operating instructions for drilling also apply to countersinking. Of particular importance are correct choice of tool and cutting speed, safe chucking of the tool and firm mounting of the work piece.

1. The setting of the depth of a countersinking

Firmly mounted drilling machines should be used for countersinking. They allow the setting of the depth of a countersinking, as for example the pillar drilling machine described on page 60. The drill spindle sleeve has a millimetre graduation arranged between gear case and spindle head. A ring is put on the drill spindle sleeve; this ring can be clamped. When the drill spindle sleeve is advanced downward, it can move only as far as this ring at the spindle

Fig. 147 Setting the depth of a countersinking

1 = Upper part of the spindle head
2 = Drill spindle sleeve with millimetre graduation
3 = Lockable ring (stop)
4 = Depth of countersinking



head will permit. If, for example, the ring is clamped at the 15-millimetre mark with the drilling machine in initial position, the drill spindle (with the chucked countersink) can advance only by 15 millimetres.

2. Burring

Drilled, cast, or punched circular openings frequently have a burr or a beaded edge. Burrs or beads are removed by use of the countersink with the view of slightly chamfering the edge of the drill hole or opening. The depth of countersinking for burring is set in such a way that the chamfer can be felt with the finger and is still just visible with the naked eye.

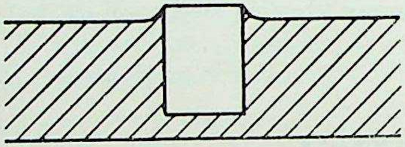


Fig. 148 Drill hole with burr

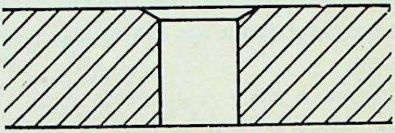


Fig. 149 Burred drill hole

3. Enlarging

The countersink can also be used to enlarge drill holes. The result obtained is a tapered chamfer or countersinking. In general, we distinguish into countersinkings for countersunk head rivets and countersinkings for countersunk head screws.

Countersinking for countersunk head rivets

The angle of countersink is of particular importance to a countersinking which is designed to accomodate the head of a countersunk rivet. However, it does not matter when the countersink has a larger diameter than the head of the countersunk rivet because the required depth of countersinking is adjusted by means of the depth setting device at the pillar drilling machine. However, if the countersinking made is too deep, the countersunk rivet will not flush with the surface of the work piece.

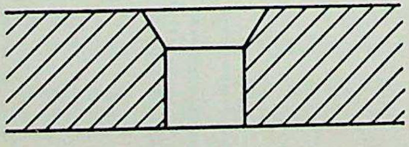


Fig. 150 Countersinking for countersunk head rivets

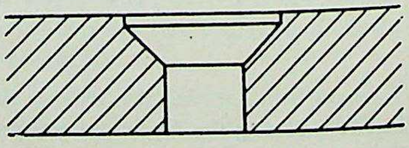


Fig. 151 Countersinking for a countersunk head screw

Countersinking for countersunk head screws

Again it is important to select the appropriate angle of countersink when countersinking a hole for a countersunk head screw. Unlike countersunk head rivets, countersunk head screws have a small cylindrical rim at the end of the screw head which must be accomodated in the enlarged part of the hole. In this case, the countersink must have the same diameter as the cylindrical rim of the countersunk screw.

III. SURVEY OF DIFFERENT TYPES OF COUNTERSINKS AND THEIR APPLICATION

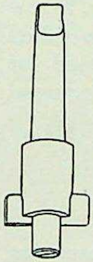


Fig. 152

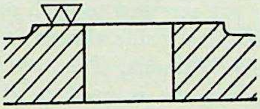


Fig. 153

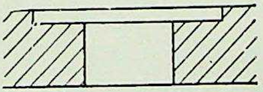


Fig. 154

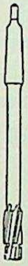


Fig. 155

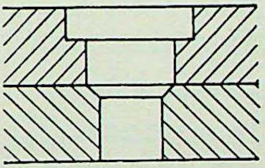


Fig. 156

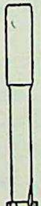


Fig. 157

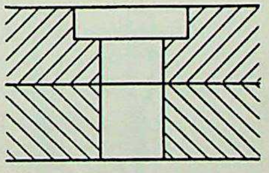


Fig. 158

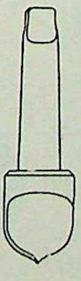


Fig. 159

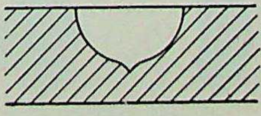


Fig. 160

Fig. 152 Flat head countersink

Fig. 153 Countersunk cast hole

Fig. 154 Countersunk seat

Fig. 155 Counterbore

Fig. 156 Countersinking made by the counterbore

Fig. 157 Head counterbore

Fig. 158 Countersinking made by the head counterbore

Fig. 159 Form countersink

Fig. 160 Countersinking made by the form countersink

J. THE CUTTING METHOD OF HAND THREADING

When cutting by means of the tap, threads are cut into the wall of drill holes. When the threading die is used for cutting, threads are cut into bolts. Hand threading is not economical in many cases, and thus it only is applied where threading by machine is impossible for technical reasons.

I. THE TAP AND THE THREADING DIE

Many machines and implements are composed of many parts. Often it is necessary to dismantle machines or implements. A machine or an implement can easily be dismantled, if the single parts are screwed to each other. Screw joints consist of inside and outside threads. The inside thread is also called female thread; screws or bolts have outside threads. The tap is used for cutting inside threads, whereas the threading die is used to cut external threads.

1. Design of the tools

Tap

The tap resembles a very hard screw which is provided with chip breaking flutes. The lower part of the tap is somewhat tapered so that it can well attack the wall of the drill hole. The upper part of the tap consists of a shank ending in a square.

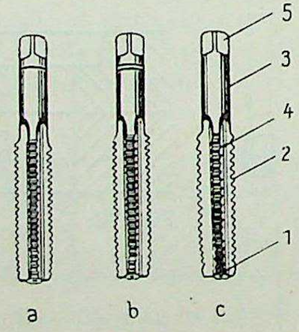


Fig. 161 A set of taps

a) Taper tap
b) Plug tap
c) Bottoming tap

1 = Chamfer
2 = Thread profile (form of the cutting thread rib)
3 = Shank
4 = Chip-breaking flutes
5 = Square

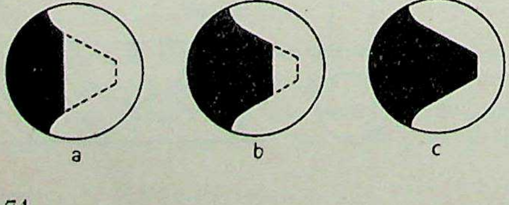


Fig. 162 Thread profiles of taps
a) Thread profile of the taper tap
b) Thread profile of the plug tap
c) Thread profile of the bottoming tap

For cutting a female thread, *a set* of taps is used. This set consists of three taps, distinguished into the taper tap, the plug tap, and the bottoming tap. The taper tap is marked by a ring, the plug tap by two rings, and the bottoming tap is not marked. These taps differ in their screw-thread profile. The thread profile of the taper tap forms the root of a thread only, the thread profile of the plug tap is already more distinct, while the bottoming tap has the desired screw-thread profile.

The mounting device for the taps is called tap wrench. Tap wrenches are distinguished into single-hole tap wrenches, multi-hole tap wrenches, and adjustable tap wrenches. Single-hole tap wrenches are designed for one specific set of taps, multi-hole tap wrenches usually can be used with four different sets of taps, whereas adjustable tap wrenches are designed for different sets of taps.

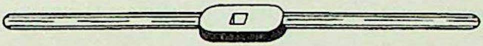


Fig. 163 Single-hole tap wrench

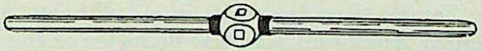


Fig. 164 Multi-hole tap wrench

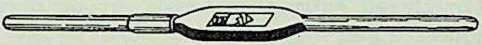


Fig. 165 Adjustable tap wrench

Threading die

The threading die resembles a very hard nut provided with chip breaking flutes.

Threading dies are single-cutting tools, that is to say, the desired thread profile is obtained in a single pass of this tool.

Die-stocks provided with threaded pins (headless pins) are used as holding devices for threading dies. When the threading die has been inserted into the stock, the threaded pins are tightened so that they engage in the drill holes of the die.

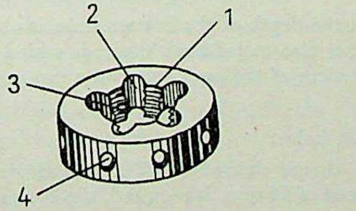


Fig. 166 Threading die
1 = Throat of threading die
2 = Chip breaking flutes
3 = Thread profile (form of the thread rib)
4 = Drill holes for the holding device (stock)

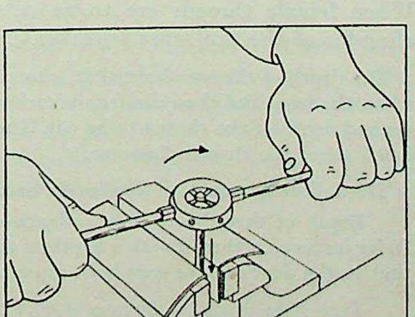


Fig. 167 Die-stock with threading die

2. Action of the tools

First only part of the material to be detached is cut out by the chamfer of the tap or the throat of the threading die while the remaining part of the material is squeezed and pressed into the space between the thread ribs of the tool. When cutting is continued, also the squeezed material is removed, because then the fully profiled thread ribs of the tool come into action.

II. WORKING WITH THE TAP AND THE THREADING DIE

A screw joint will only function satisfactorily when external and internal threads match properly. Any threading tool can only be used for a specific thread and a certain diameter. When working with these cutting tools, the same cutting coolants and lubricants are used as in drilling.

1. Cutting female threads

Female threads are cut into drill holes. A drill hole for a female thread is called *thread-core hole.* The diameter of this hole (thread-core hole diameter) is dependent on (1) the diameter of the female thread and (2) the material. For thread cutting, materials are distinguished into such as are heavily squeezed and such as are only little squeezed in threading.

Some thread-core hole diameters with pertaining thread diameters for different materials are shown on page 79, paragraph III.

The thread-core hole diameter can be worked out when applying the following "rule of thumb," which is sufficiently accurate for most cases:

Core diameter × 0.8 = Thread-core hole diameter

For example:

3 mm. × 0.8 = 2.4 mm. (Thread-core hole diameter).

When female threads are to be cut into bottom holes, the length of the chamfer of the tap must be taken into account.

The depth of the core hole, that is to say, the depth of the bottom hole, is obtained when the length of the chamfer, in such cases also called back taper, is added to the desired depth of the thread to be cut. The length of the back taper of a tap generally is 0.7 times the thread diameter.

The following equation applies to bottom holes:

Depth of thread-core hole = depth of thread desired + 0.7 × thread diameter. If, for instance, a thread with a depth of thread of 20 mm. is required, the bottom hole, that is, the depth of the core hole, must be calculated as follows:

$$\begin{aligned}\text{Core hole depth} &= 20\text{ mm.} + (0.7 \times 4\text{ mm.})\\ &= 20\text{ mm.} + 2.8\text{ mm.}\\ &= 22.8\text{ mm.}\end{aligned}$$

Each thread-core hole should be slightly enlarged at the top before cutting the thread so as to obtain a small chamfer which facilitates the application of the tap.

Then the taper tap is put to the thread-core hole while a square is used to check the correct position of the tap in relation to the core hole. When the tap wrench has been mounted, cutting is started and continued until the tap is drawn into the thread-core hole without pressure from the top. Never cut a thread in one uninterrupted pass, but once the tap is cutting well, turn it back half a rotation after every two or three rotations so that the chips are being broken and can thus be easily discharged through the chip flutes. Moreover, the cutting lubricant or coolant can get to the cutting point more easily, and the flanges of the thread are being better shaped.

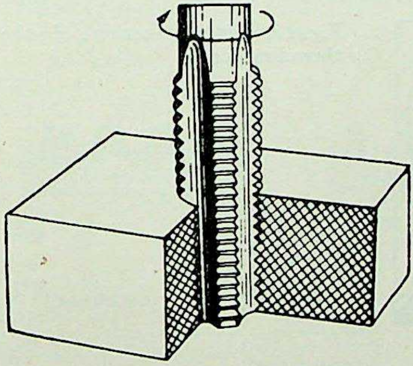


Fig. 168 Cutting action of the tap

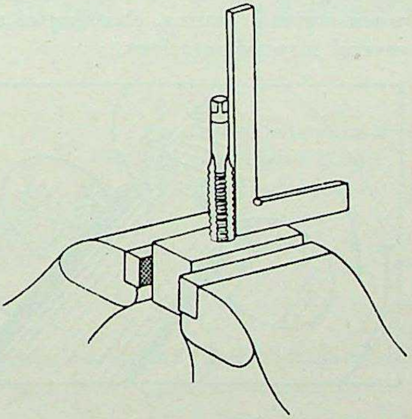


Fig. 169 Checking the correct tap position

After rough-cutting by means of the taper tap, cutting is continued with the plug tap and, eventually, with the bottoming tap. Plug tap and bottoming tap are first screwed in the pre-cut thread without the use of the tap wrench, using your fingers, until sufficient resistance is felt. Before mounting the tap wrench, the correct position of the tap should be checked. When the plug tap and the bottoming tap are used, chip escape must be ensured in the same way as with the taper tap.

2. Cutting outside threads

Outside threads are cut into *bolts*. The diameter of the bolt always is a little smaller than the thread diameter.

Generally, the following formula is used for calculating:

Diameter of bolt = thread diameter — 0.3 × depth of thread. If an outside thread is to be cut, the diameter of a bolt, for example, must be calculated in the following way:

Diameter of bolt = 6 mm. — (0.3 × 0.65 mm.)
= 6 mm. — 0.195 mm.
= 5.805 mm., = approx. **5.8 mm.**

The head of the bolt should be chamfered and filed convexly in order to enable the threading die to attack the bolt properly.

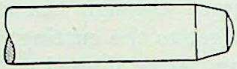


Fig. 170 Bolt head prepared for the threading die

All that has been said about cutting with the taper tap also applies to the application of the threading die and the cutting action; i.e. correct application when starting cutting, checking of correct position, half a turn back after several forward rotations.

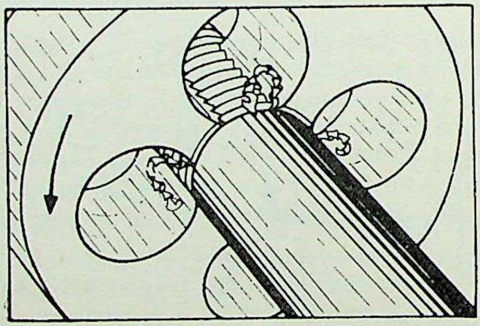


Fig. 171 Cutting action of the threading die

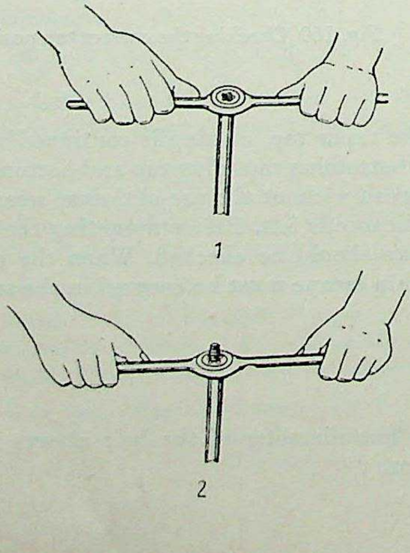


Fig. 172 Handling the die-stock

1 = Handling when starting cutting

2 = Handling when cutting further

III. SURVEY OF THE VARIOUS TYPES OF THREAD PROFILES AND THREAD-CORE HOLE DIAMETERS

The most frequently used types of threads are the metric screw-thread and the Whitworth screw-thread. Metric screw-threads are based on the *millimetre* as a unit of measure; Whitworth screw-threads on the *inch* as a unit of measure.

In engineering practice, different thread profiles are used.

For example:

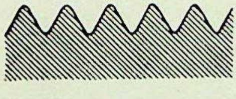


Fig. 173

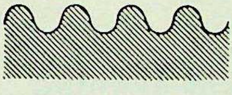


Fig. 174

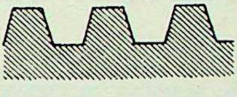


Fig. 175

Fig. 173 Angular thread
Fig. 174 Round thread
Fig. 175 Trapezoidal thread
Fig. 176 Square thread
Fig. 177 Buttress thread

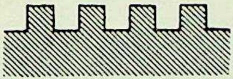


Fig. 176

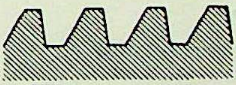


Fig. 177

Thread-core hole diamaters for some metric and Whitworth threads in mm.

	Metric threads						Whitworth threads		
Thread	M 3	M 4	M 5	M 6	M 8	M 10	¼"	⅜"	½"
Core hole in grey cast iron, brass, bronze	2.4	3.2	4.1	4.8	6.5	8.2	5	7.7	10.25
Core hold in steel, cast steel, plastics	2.5	3.3	4.1	5	6.7	8.4	5,1	7.9	10.5

To prevent accidents, observe the following hints.

Before beginning to cut make sure that:

(1) the work piece is firmly chucked,
(2) both bolts and core holes have been properly prepared,
(3) both bolts and core holes are absolutely free from chips.

Forming

K. FORMING BY BENDING

Suitable work pieces which are not too thick may be formed into angular or round shapes by manual bending.

I. METAL MATERIAL FOR BENDING

Many metals and their alloys may be formed by bending. When considering metal materials with regard to their bending properties the following facts are of importance: (1) behaviour of the materials in bending and (2) calculation of the bending length.

1. Behaviour of the materials in bending

Materials which are being bent are subjected to stress. Fig. 178. illustrates the tensile and compressive stresses involved. Dotted lines are marked out on the surface of a work piece. When the work piece is being bent, as seen in Fig. 179, then the lower dotted line becomes shorter along the inner edge of the bend. The dotted line along the outer edge of the bend grows longer. The shortened line is characteristic of the compressive stress, the elongated line of the tensile stress involved.

The dotted line in the middle remains unchanged. The neutral part of the work piece is located about this middle line. This neutral part is of importance to the calculation of the bending length to be made later on.

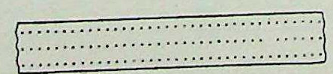


Fig. 178 Work piece with dotted lines marked on its surface

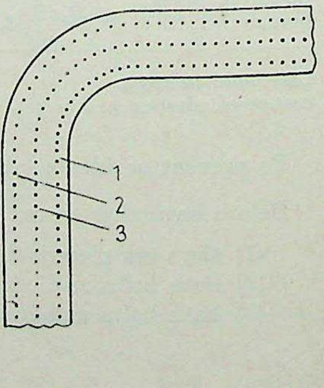


Fig. 179. Bent work piece
1 = Part of the work piece subjected to compressive stress
2 = Part of the work piece subjected to tensile stress
3 = Neutral part

2. The calculation of the bending length

The work piece seen in Fig. 179 is shown subdivided into the sections 1, 2 and 3 in Fig. 180. This subdivision is marked out on the neutral part of the work piece. The three sections are called the three partial lengths (abbreviation l).

1 represents partial length l_1,
2 represents partial length l_2,
3 represents partial length l_3.

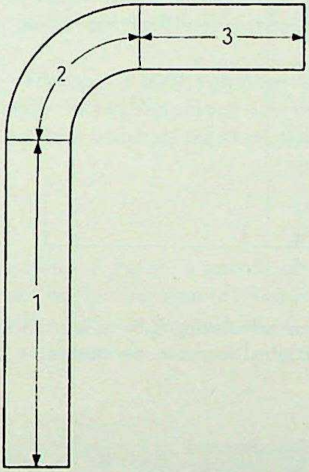


Fig. 180 Partial lengths marked out on the work piece

In the first place, the partial length l_2 is of particular interest. Its radius R and the bending radius r are of particular importance. We must also know the thickness of the work piece.

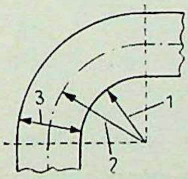


Fig. 181. For calculating partial length l_2

1 = Radius R on the neutral part
2 = Bending radius r
3 = Thickness of the work piece

In case of a rectangular bend, the partial length l_2 is a quarter circle which is calculated as follows:

$$l_2 = \frac{\pi}{2}\left(r + \frac{1}{3}s\right)$$

Where

π = Symbol of ratio of circumference of circle to diameter (3.14)
r = Bending radius
s = Thickness of work piece

The value $\frac{1}{3}s$ is an approximate value established by practice; the neutral part of the work piece stretches exactly along the centre of the work piece under certain conditions only. Mostly the neutral part is inside that third part which forms the inner edge of the bend. If, for example, the bending length of the work piece is to be calculated according to a drawing at hand, then we have to proceed as follows:

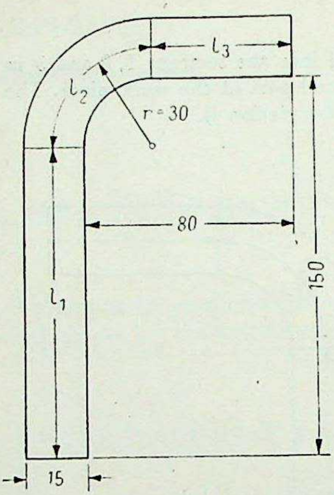


Fig. 182 Workshop drawing for the calculation of a bending length

Bending length $l = l_1 + l_2 + l_3$

First we calculate l_2 and l_3.

$l_1 = 150$ mm. $- r$

$l_1 = 150$ mm. $- 30$ mm.

$l_1 = \underline{\mathbf{120\ mm.}}$

$l_3 = 80$ mm. $- r$

$l_3 = 80$ mm. $- 30$ mm.

$l_3 = \underline{\mathbf{50\ mm.}}$

$l_1 + l_3 = 120$ mm. $+ 50$ mm.

$l_1 + l_3 = \underline{\mathbf{170\ mm.}}$

When calculating l_2 by using the above mentioned formula, we obtain:

$$l_2 = \frac{3.14}{2}\left(30 + \frac{1}{3}\,15\right)$$

$$l_2 = \frac{3.14}{2}\,(30\text{ mm.} + 5\text{ mm.})$$

$$l_2 = \frac{3.14}{2}\,35\text{ mm.}$$

$l_2 = 54.95$ mm., = approx. $\underline{\mathbf{55\ mm.}}$

Bending length $l = (l_1 + l_3) + l_2$

Bending length $l = 170$ mm. $+ 55$ mm.

Bending length $l = \underline{\mathbf{225\ mm.}}$

In several cases the partial length l_2 can also be worked out from a "rule of thumb" with satisfactory accuracy, namely: Partial length $l_2 = \frac{1}{2}\,r +$ thickness of sheet-metal.

For example:	given:	wanted:
	Thickness of sheet-metal $s = 12$ mm.	Partial length l_2
	Bending radius $r = 20$ mm.	

Solution: $l_2 = \frac{1}{2}\,r + s$ $\qquad l_2 = 10\text{ mm.} + 12\text{ mm.}$ $\qquad l_2 = \underline{\mathbf{22\ mm.}}$

II. BENDING WORK

In principle, bending work is distinguished into cold bending and hot bending. The decision whether bending is to be done with the material in a cold or hot state is dependent on the hardness of the material in question and the size of the section to be bent, no matter whether bending is to be performed by hand or by means of a bending machine or bending punch. The examples of bending work dealt with below refer to cold bending. When considering bending work, the following factors are of particular importance: (1) tools, (2) bending angular shapes, and (3) bending round shapes.

1. Tools

Apart from the known chucking tools, protective jaws, auxiliaries, and marking tools, the mallet and the round nose pliers are frequently required for bending.

When a work piece is marked for bending, generally a lead pencil is used instead of the scriber. The notching action of scribers could damage the work piece to such an extent that it cracks or breaks if the bending point coincides with the marking line.

2. Bending angular shapes

If cold-rolled sheet-metal is to be bent, the flow of grain, a result of the rolling direction, must be taken into account. Such sheet-metal tends to break at the bending point, in particular with acute-angled bends, if the bending edge is running in the same direction as the grain.

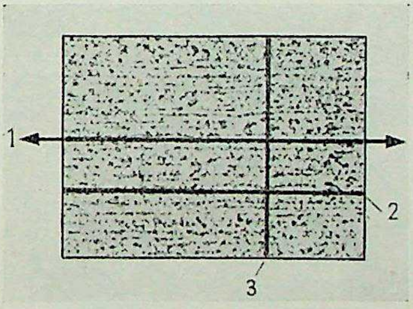


Fig. 183 Flow of grain and bending edge

1 = Flow of grain
2 = Wrong bending edge selected, the sheet-metal may break
3 = Proper bending edge selected

There are many ways of bending angular shapes. Here we shall deal with bending long sides and bending small sides of work pieces, and bending square clamps.

Bending long sides of work pieces

When long sides are to be bent, work pieces of steel must be chucked in the vice without protecting jaws, work pieces of light metal in a vice with protecting jaws. Then the mallet is used for striking the work piece where the bending edge is wanted until the desired angle is obtained. If the material is beaten far off the bending edge, or at the free end of the side, the work piece will be distorted.

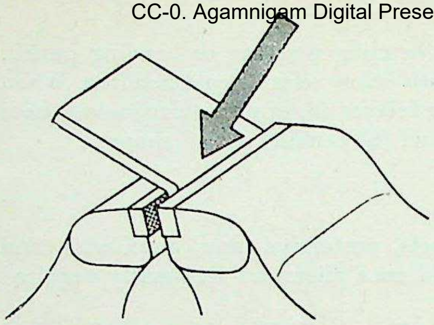


Fig. 184 Proper way of bending the long side of a work piece

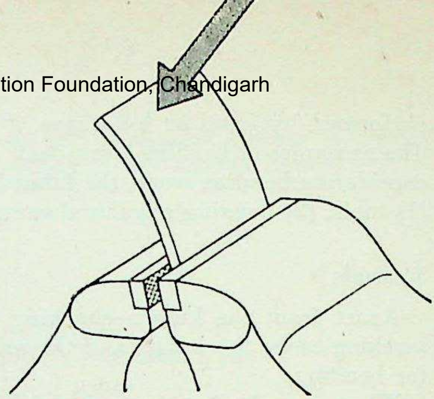


Fig. 185 Wrong! The long side will be distorted!

Bending small sides of work pieces

When small sides are to be bent, a piece of hard wood should be used having a width equal to the length of the side to be bent. The piece of hard wood must be placed on the work piece with the lower edge along the bending edge and then beaten by means of the fitter's hammer until the work piece shows the desired angle.

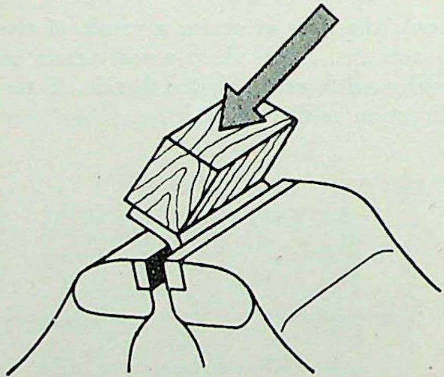


Fig. 186 Proper way of bending the short side of a work piece

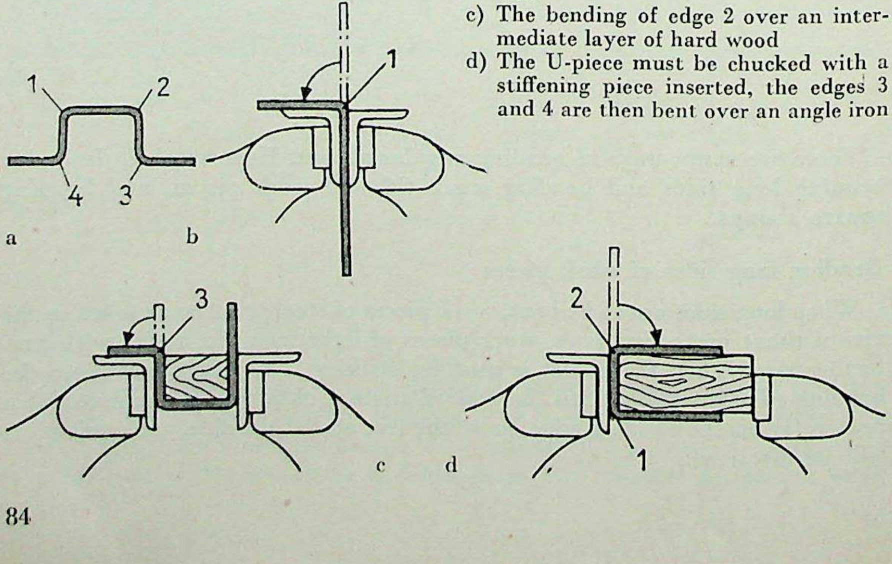


Fig. 187 Bending a square clamp

a) Profile of the clamp 1, 2, 3, 4 Bending edges
b) The bending of edge 1 over an angle iron
c) The bending of edge 2 over an intermediate layer of hard wood
d) The U-piece must be chucked with a stiffening piece inserted, the edges 3 and 4 are then bent over an angle iron

Bending a square clamp

Sharp edges as are desired in square clamps are obtained when the work piece is bent over a sharp-edged angle iron. These angle irons are chucked in the vice in the same way as the protecting jaws.

3. Bending round shapes

Sheet-metal is bent round by means of bending blocks used in addition to the tools described above. Bending blocks are round sections of metal or hard wood with bends showing the shape of the bends required in the work pieces in question. The round nose pliers are used for bending thin wire. There are many ways of bending material round. Here we shall deal with bending a half-round clamp and bending a wire eyelet.

Bending a half-round clamp

When the work piece has been cut to the desired length, three marking lines are required, that is to say, two lines marking the bending edges and one line marking the centre of the clamp.

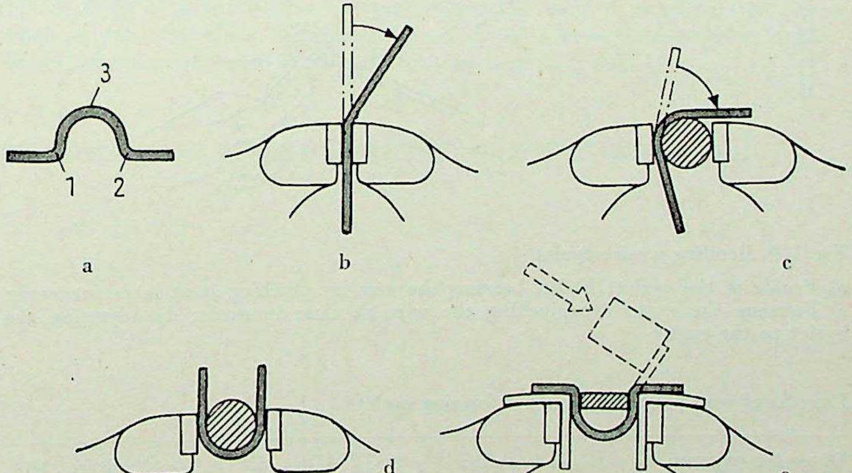


Fig. 188 The bending of sheet-metal into a half-round clamp

a) Profile of the clamp; 1, 2 Bending edges; 3 Centre of the clamp
b) Slightly pre-bending the material in the centre
c) Rough-rounding the material over the bending block
d) Fully rounding the material by tightening the vice
e) The U-piece must be chucked with a stiffening piece inserted and then the flanges of the clamp bent in the desired angle

Bending a wire eyelet

Generally, wire eyelets must have a certain diameter.

The approximate length of the piece of wire required for the production of the eyelet is calculated according to the following equation:

$$l = d \times \pi$$

where

d = Required diameter of the wire eyelet
π = Symbol of ratio of circumference of circle to diameters (3.14).

If, for instance, the wire eyelet is to have a diameter of 4 mm., the wire end needed to form the eyelet must be approximately 12.7 mm. long. This means that a 12,7 mm. long piece of wire must be bent uniformly round into a fully closed eyelet by means of the round nose pliers.

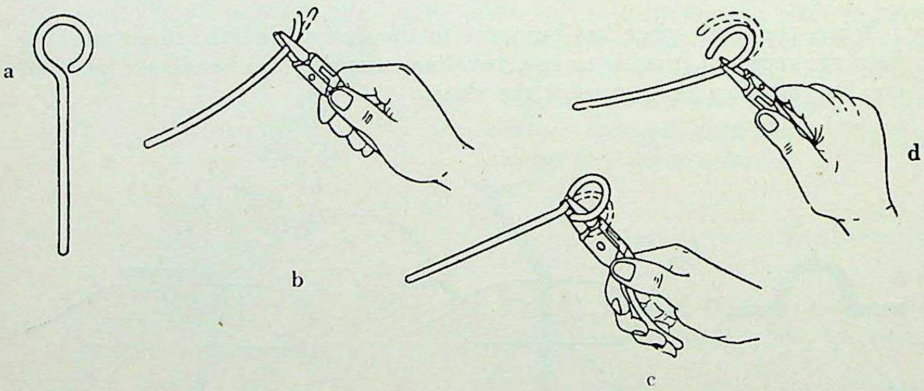


Fig. 189 Bending a wire eyelet

a) Profile of the eyelet; b) Pre-bending the wire by pinching it at large intervals; c) Forming the eyelet by pinching the wire at close intercals; d) Adjusting the eyelet to the centre

Lengths of wire pieces required for forming eyelets

Diameter (d) mm.	2	2.6	3	4	5	6	8	10
Length of wire piece (l) mm.	7	8.8	10	13.5	17	20	26	33

Bending tubes

Tubes will become deformed at the bending point, that is to say, they get flat. Therefore, it is necessary to fill fine, dry sand into the tubes to be bent and close the tube ends with wooden plugs.

The internal space of the tube grows larger during bending. As a consequence the sand filling gets loose. Therefore, the plugs must repeatedly be driven in deeper.

When a tube is being bent, the tube wall forming the inner bend grows thicker and the tube wall forming the outer band gets thinner.

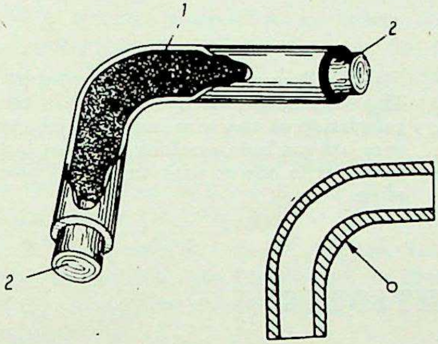


Fig. 190 Bending a tube filled with sand

1 = Sand filling
2 = Plug

Fig. 191 The inner bend becomes thicker and the outer bend thinner

This may be a great disadvantage when the tube is subjected to stress when in use. Therefore, it is advisable to bend a knee with a great radius. Tubes with diameters up to 13 mm. may be bent in a cold state.

III. SOME FAULTS FREQUENTLY MADE IN BENDING

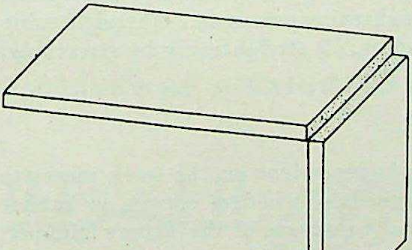


Fig. 192 Crack at the bending edge

Cracks at the bending edge may be due to a material with poor bending properties (too brittle or too hard), to the fact that the flow of grain has been disregarded or the material has been marked by means of the scriber.

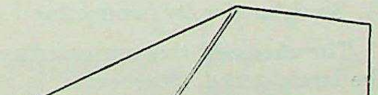


Fig. 193 Oblique bending edge

An oblique bending edge may be caused by chucking the work piece obliquely, by a wrong application of the intermediate piece of hard wood, or by hammering one side only.

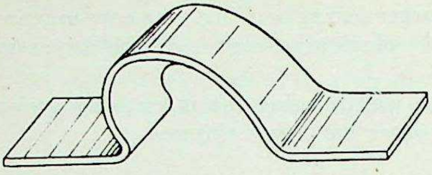


Fig. 194 Improper roundness of the bent strip of sheet-metal

This may occur when the strip of sheet-metal is bent too much at the beginning, when the diameter of the bending block deviates from the desired diameter of the bend to be made, or when bending was done without watching the centre.

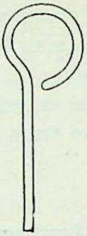


Fig. 195 Poor roundness of a wire eyelet. This may be caused by an error in the calculation of the wire length, or if the wire has not been carefully pre-bent but was bent in one go with the round nose pliers.

L. FORMING BY STRAIGHTENING

Distorted, undulated or battered work pieces are restored to a useful condition by straightening.

I. STRAIGHTENING PROCESSES

Work pieces may have been deformed by improper storing, careless transportation or improper treatment to such an extent that they are no longer of any use. Therefore, they must be straightened. Here we are going into detail on the following different straightening processes: (1) straightening by hammering, (2) straightening by bending, (3) straightening by stretching, and (4) straightening by heating.

1. Straightening by hammering

The choice of the straightening tools is dependent on the work pieces to be straightened. Sheet-metal is straightened by wooden, copper, or rubber hammers. Sections are usually straightend by means of the fitter's hammer. Internal stresses may occur in a work piece, as has already been mentioned in connexion with bending (see page 80). Battered or undulated sheet-metal and distorted sections show internal stresses which are balanced, that is, removed by the counter-stresses induced by hammering.

2. Straightening by bending

Strips of sheet-metal and square sections which are not too thick can be straightened by bending. In such cases, the vice is used as a holding fixture and the straightening rod for the straightening procedure proper. In general, a straightening rod is adapted to a certain section size and can thus be used for this size only. However, straightening rods are easily made and should be prepared for the usual section sizes so as to be always ready at hand.

3. Straightening by stretching

Thin distorted wires are straightend by stretching them longitudinally. There are two methods of stretching wires, namely, stretching over a piece of round wood and stretching by means of a clamp dog. Generally, long pieces of wire are straightened by drawing them over a round piece of wood. For this purpose, the wire is clamped in a vice at one end and then drawn over the piece of round wood by hand.

Small pieces of wire are clamped in a vice at one end, while the other end is clamped in a clamp dog. Also in this case, the wire should be stretched by hand only.

When stretching wires in order to straighten them, take into account that the wire section may be reduced. In most cases, this is undesired. Therefore, after completing stretching, check whether the diameter still shows the required size.

4. Straightening by heating

Thick pieces of section iron which are but slightly bent or buckled can be straightened by heat. This straightening method makes use of the expansion of the metal caused by heat. Only a limited area is heated up while the bordering areas of the work piece are cooled. When the work piece cools down, the desired shape of the section is restored by the stresses involved in this process.

II. SURVEY OF STRAIGHTENING OPERATIONS

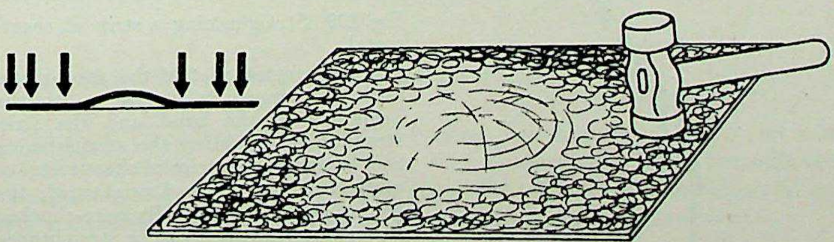


Fig. 196 Straightening undulated sheet-metal

The parts of the sheet contacting the support are hammered, beginning from the outer edge and proceeding towards the centre. Approaching the centre, the frequency of hammering must be increased.

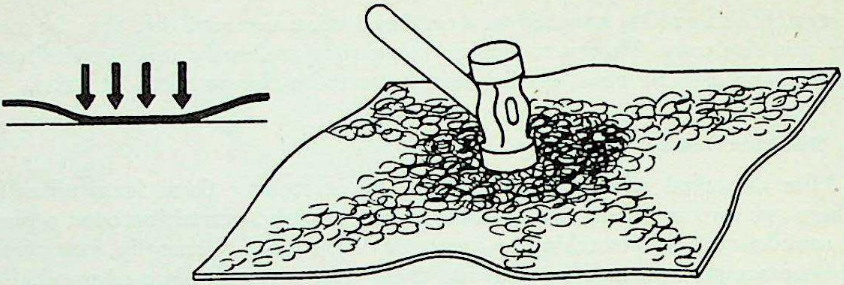


Fig. 197 Straightening battered sheet-metal

The parts of the sheet contacting the support are hammered, beginning from the centre and proceeding towards the edges of the sheet in a spiral. When approaching the edge of the sheet, the frequency of hammering must be in creased.

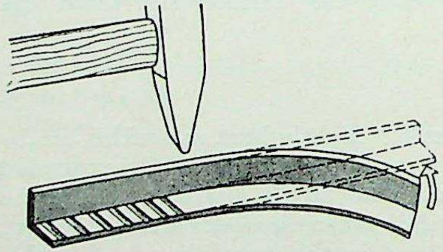


Fig. 198 Straightening a piece of angle iron

The upset part of the angle iron is straightened by the pane of the fitter's hammer

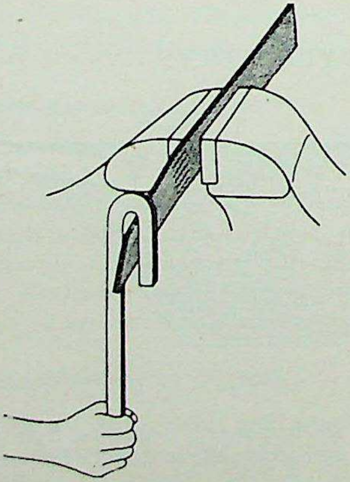


Fig. 199 Straightening a strip of sheet-metal

The undistorted part of the sheet-metal strip is clamped in a vice up to the beginning of the bend and the strip straightened by using the straightening rod. When longer strips of sheet-metal or steel band are to be straightened, the work piece must repeatedly be re-chucked in such a way that it can be straightened in small portions.

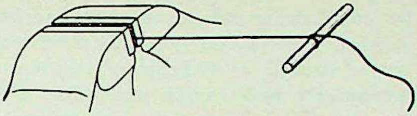


Fig. 200 Straightening thin wire

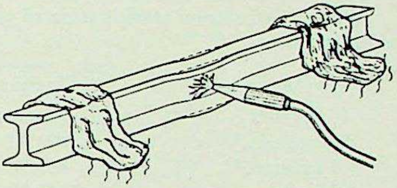


Fig. 201 Straightening a TT-section
Heat the longitudinal leg of the TT-section. At the same time cool the parts at either side of the bend by means of wet cloths.

To prevent accidents during bending and straightening, observe the following hints.

Before beginning to bend or straighten, make sure that

(1) the hammer handle is firmly fixed in the hammer head,
(2) the work piece shows no burr,
(3) the work piece and, if used, the intermediate shims are tightly chucked,
(4) the straightening plate has a firm hold.

M. FORMING BY FORGING

Forging is a method of shaping without cutting, applied to work pieces which are more ductile at temperatures higher than room temperature. Thus, material can be saved by forging. Moreover, forged work pieces often show a greater strength than similar work pieces which were shaped by cutting.

I. METAL MATERIALS FOR FORGING

In most cases steel is worked by forging. Furthermore, copper and some aluminium alloys are forged too. For forging metal materials, the following factors are to be taken into consideration: (1) behaviour of the material and (2) calculation of the rough length (length in unwrought condition).

1. Behaviour of the material

There are many possibilities of testing the behaviour of materials. For testing the forging properties, the *tensile strength* test is of particular importance. This test means that, for example, a metal rod having a section of 1 mm.^{2} is loaded by weights in longitudinal direction (that is, the rod is exposed to tension load). In this way, the strength of this metal rod can be determined. When a steel quality is stated to have a tensile strength of 40 kg./mm.^{2}, this means that a rod of this steel quality having a section of 1 mm.^{2} can be exposed to a tension load of 40 kg. Materials suitable for forging change their tensile strength under the effect of heat. The following relations are true: high tensile strength — poor ductility, low tensile strength — great ductility.

Here, the structural steel is selected to show an example of the ductility under the effect of heat.

Tensile strength	Temperature
40 kg./mm.^{2}	Room temperature
12 kg./mm.^{2}	600 °C (low red heat)
4 kg./mm.^{2}	900 °C (yellow-red heat)
2 kg./mm.^{2}	1100 °C (light-yellow heat).

If structural steel is to be forged with best results, this material must be brought to a light-yellow heat.

2. Calculating the rough length

The calculation of the rough length of the unwrought work piece is very important in order to save material. After calculating the rough length, the required length for forging must also be determined.

When calculating the rough length, we start from the consideration that the volume of the work piece has not, or only very little, changed after forging.

Volume of the work piece before forging ≈ Volume of the work piece after forging. Generally, the volume of a work piece is calculated as follows:

$$V = A \times l$$

where
V = Volume
A = Section
l = Length

When we are going to determine the rough length, we must relate the volume of the work piece to be forged (stated in the workshop drawing) to the section of the unwrought piece according to the following equation:

$$\text{Rough length} = \frac{\text{Volume of the finished piece}}{\text{Section of the unwrought piece.}}$$

Example:

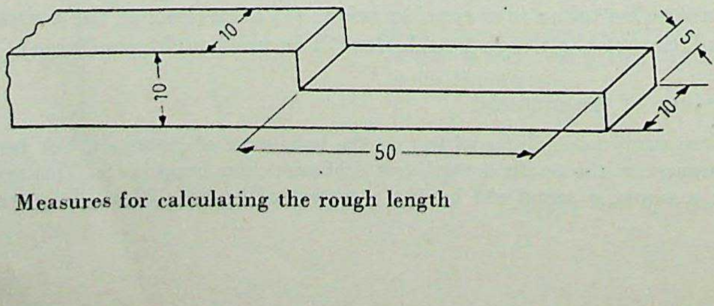


Fig. 202 Measures for calculating the rough length

As can be seen in Fig. 202, the measures of the lug to be forged are

50 mm. × 10 mm. × 5 mm.

these are the available measures for calculating the rough length. Hence, the volume of the finished piece is

50 mm. × 10 mm. × 5 mm.
= **2500 mm.^{3}**

As shown in Fig. 202, the section of the unwrought piece is

10 mm. × 10 mm.
= **100 mm.^{2}**

It follows that

$$\text{rough length} = \frac{2500 \text{ mm.}^3}{100 \text{ mm.}^2}$$

= **25 mm.**

When we take this result as a basis, a distance of 25 mm. should be marked off from the end of the work piece, and then this length be forged. However, the result obtained in this way would not be satisfactory, because forging involves loss in material due to roasting residue (forging scales) and compression of the material. Therefore, a material allowance of 10 to 20 per cent should be added, depending on the size of the work piece.

In this case, we add an allowance of 20 per cent and obtain a forging rough length of 25 mm. + 5 mm. = **30 mm.**

II. FORGING EQUIPMENT AND TOOLS

The workshop where material is forged is called a "forge". It differs from other metal working shops by (1) the forging equipment and (2) the tools.

1. Forging equipment

The forging equipment includes the forging furnace or portable forge, the anvil, and the swage block.

Forging furnace

Fig. 203 shows a forging furnace made of steel. This has replaced the blacksmith's hearth built with bricks which was in use formerly.

The flow of air can be changed by adjusting a nozzle provided at the fire pane. In this way, different temperatures for heating the pieces to be forged are obtained. In principle, the furnace should be erected where it is not exposed to direct sunlight. The different forging, annealing and heat colours can be better made out with the forging furnace in the shade.

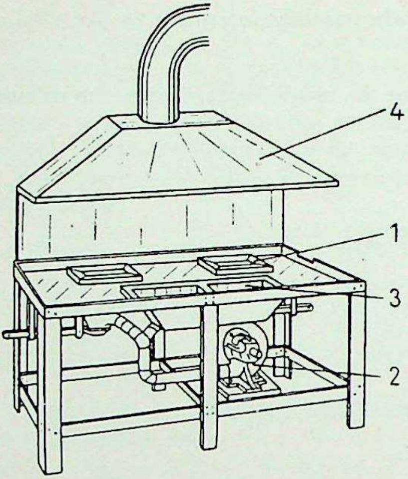


Fig. 203 Forging furnace

1 = Fire pane
2 = Blower with electric motor
3 = Quenching tank
4 = Chimney hood

Portable forge

Fig. 204 shows a portable forge. It is particularly suitable for forging at construction sites. Owing to its small size and light weight this forge can easily be transported. However, the foot-operated blower used on this forge is a disadvantage of this design.

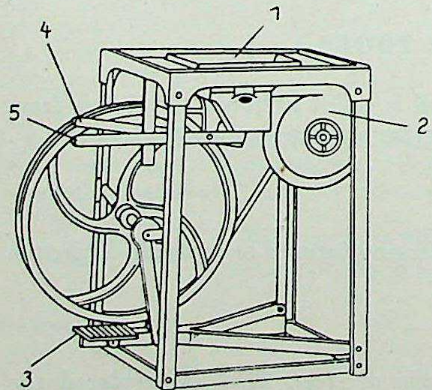


Fig. 204 Portable forge

1 = Fire pan
2 = Blower
3 = Foot-actuated drive
4 = Flow-of-air regulating device
5 = Poker

Fig. 205 shows a common forge anvil. Various forging operations, such as upsetting, offsetting, and forging-out, can be performed by using this anvil. The forge anvil should be mounted on a wooden block secured by hoop irons against splintering.

The following fuels are burnt in the forging furnace or the portable forge:

(1) forge coal (2) forge coke (3) charcoal.

Anvil

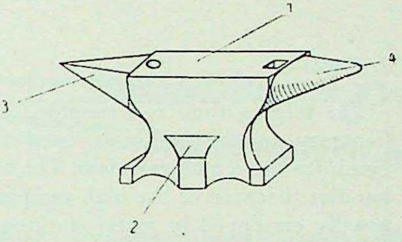


Fig. 205 Anvil

1 = Anvil face
2 = Anvil heel
3 = Square anvil horn
4 = Round anvil horn

The following survey shows the field of application of these fuels:

Fuel	Advantages	Disadvantages	Application
Forge coal: small coal, having the size of a walnut	Heavy weight; high temperature of combustion; good blacksmith's slag	Contains many impurities	Suitable for all forging operations; forging at high temperatures
Forge coke; small metallurgical coke	Burns with a clear flame, the work piece can be watched well in the fire	The fire is not a compact whole and will go out soon	For all forging operations; forging at high temperatures
Charcoal: carbonized wood, heated up under exclusion of oxygen	Burns with a small, clear flame; little residues	Light weight; no high temperatures, burns down too quickly, not economical for large work pieces	Only for small work pieces

The swage block

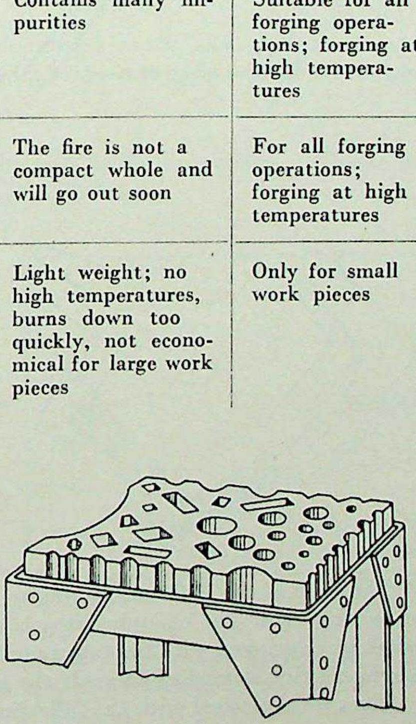


Fig. 206 The swage block

Fig. 206 shows a swage block. This block serves (1) as bottom die (matrics-die) for punching operations and (2) to accomodate bottom swages. The swage block is supported by a steel frame made of reinforced angle steel, and should be mounted in such a way that it is but little resilient.

2. Tools

The forging tools can roughly be distinguished into hammers and tongs. Contrary to the hammers used for the usual hammering work, forging hammers have a bigger mass. The tongs used for forging mostly have longer handles (because of the high temperature of the work pieces) than the tongs usually employed in metal working.

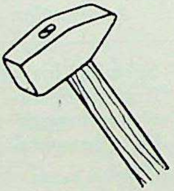


Fig. 207 Hand hammer: Weight about 1 to 2.5 kg.

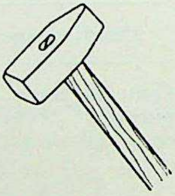


Fig. 208 Cross-pane sledge. This sledge is used when several persons are working one work piece. The pane of the sledge must beat the work piece in the same direction as the pane of the hand hammer or the sledge hammer.

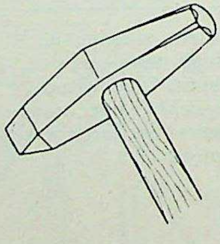


Fig. 209 Planishing hammer. This hammer is used to finish rough-forged surfaces. The head of the hammer is rounded to prevent the hand hammer from slipping off when it hits this head.

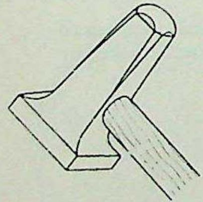


Fig. 210 Hot chisel. It is provided with a rounded head similar to that of the planishing hammer. Thick sections are parted by means of the hot chisel at forging temperatures.

The jaws of the different forging tongs are adapted to the different shapes of work pieces. The clamping ring is an essential device of these tongs. The work piece gripped with the tongs can be firmly clamped in the jaws when the clamping ring is pushed towards the ends of the handle.

Here we shall deal with the following tongs:

Fig. 211 Blacksmith's straight lip tongs
1 = Jaws
2 = Eye
3 = Handle
4 = Clamping ring

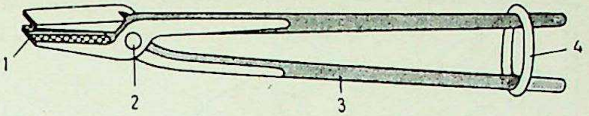


Fig. 212 Blacksmith's double pick-up tongs

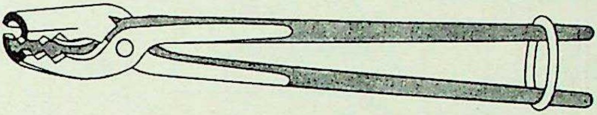
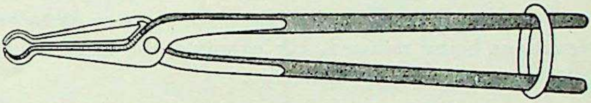


Fig. 213 Riveting tongs



III. FORGING OPERATIONS

The forging operations can be distinguished by the way in which the work pieces are shaped. We distinguish into (1) hammer forging and (2) die forging.

1. Hammer forging

In this forging method the work piece is freely moved between anvil and hammer, where it is forged into the desired shape.

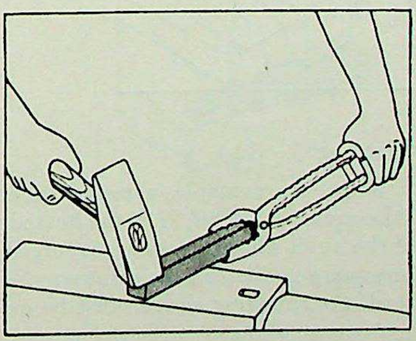


Fig. 214 The proper way of handling the blacksmith's tools

The work piece is forged into the desired shape either by upsetting, offsetting, or forging-out the work piece. The operations may also be involved in forging one single work piece.

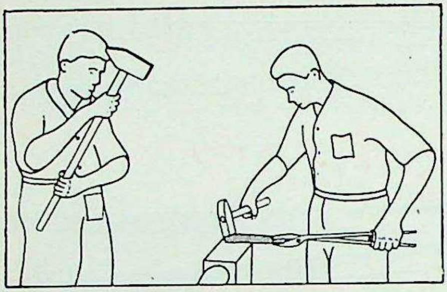


Fig. 215 This is how the sledge hammer is handled

Upsetting

Upsetting means forging the work piece so as to become thicker while its length is being reduced. For example, the heads of bolts, rivets or nails are often pre-worked by upsetting.

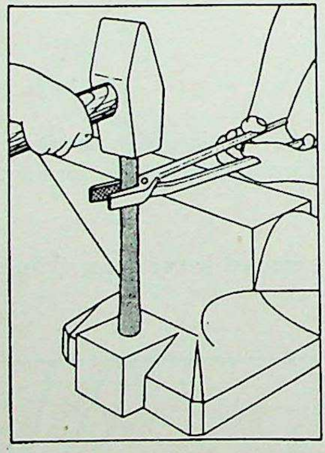


Fig. 216 Upsetting the head of a bolt; this increases the strength of the bolt head

Offsetting

When, for example, a round section iron is wanted to end in a square, "the square is set off," i. e. the heated round section iron is placed on the edge of the anvil while the square is forged, that is, set off. Flat lugs can be forged on square sections in the same way. If the square section is to end in a round stud, the rounding swage must be used for offsetting.

Forging-out

Generally, forging-out means extending a work piece longitudinally. In such cases, the section of a work piece is uniformly reduced while the work piece is extended in the same proportion. There are also other methods of forging-out, which are called flattening, pointing, and sharpening.

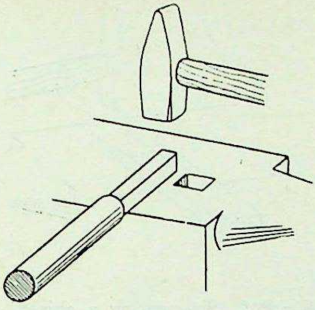


Fig. 217 Offsetting a square stud

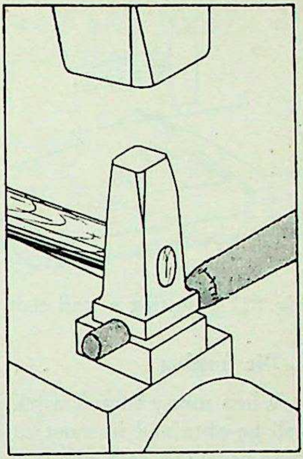
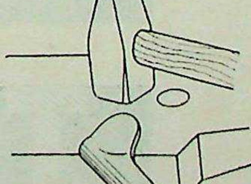


Fig. 218 Offsetting a round stud

If, for example, a stone bolt is to be forged, the end of the round-section material must first be flattened in such a way that flaps can be formed.

Pointing is the method of forging wall hooks and wall clamps. The section of the material is gradually reduced so that the end forms a point.

Fig. 219 Forging-out a work piece



When a piece of flat material is forged into a chisel, the flat material is first extended edgewise and then sharpened to a wedge by hammering on the broad sides.

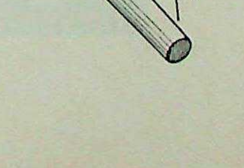


Fig. 220 Flattening the flaps of a stone bolt

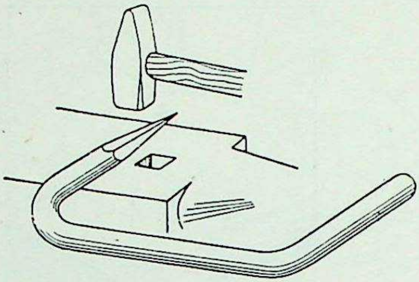


Fig. 221 Pointing a wall clamp

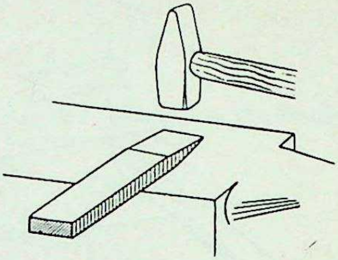


Fig. 222 Sharpening a chisel

2. Die forging

When many forged work pieces of the same kind are required, best results will be obtained in most cases with an auxiliary device, the so-called die. All that has been said about marking by means of the template (see page 22), analogously applies to economical forging.

The die is a mould which may consist of several parts. The heated work piece is put into this mould while part of the piece projects from the mould. Then the work piece is beaten into the mould by means of the blacksmith's hammer until it fully fills the mould. There are various ways of die forging; here, forging by means of the rivet forming die is illustrate.

Rivet forming die

The rivet forming die is a one-part mould. The rivet head is formed by the upper hollow space of the mould.

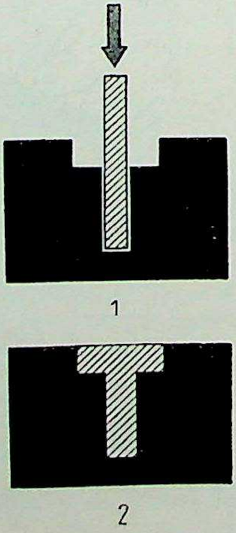


Fig. 223 Rivet forming die
1 = Blank inserted in the mould
2 = Forged rivet

IV. SURVEY OF FORGING TEMPERATURES AND HEAT COLOURS OF DIFFERENT STEEL QUALITIES

Forging temperature	Maximum forging temperature	Colour	Minimum forging temperature	Colour
Construction steel	1100 °C	light-yellow	720 °C	dark-red
Tool steel	1000 °C	yellow-red	750 °C	dark cherry-red
High-speed steel	1200 °C	light-yellow	1000 °C	dark-yellow

Survey of heat colours

Heat colour	Temperature range (°C)
Dark-brown	520 to 580
Brown-red	580 to 650
Dark-red	650 to 750
Dark cherry-red	750 to 780
Cherry-red	780 to 800
Light cherry-red	800 to 830
Light-red	830 to 880
Yellow-red	880 to 1050
Dark-yellow	1050 to 1150
Light-yellow	1150 to 1250
White	1250 to 1350

In order to prevent accidents in forging, observe the following hints. Before beginning to forge, make sure that,

(1) the hammer handle is firmly fixed in the head,
(2) the anvil is firmly erected,
(3) swage block and dies are properly supported,
(4) the correct forging tongs have been selected,
(5) you have put on your protecting clothes.

Joining

N. JOINING BY SCREWS

Screws are used to join such components as, by there nature or function, must be capable of being disconnected and, when doing this, neither the components nor the joining elements must be damaged.

I. CHOICE OF TYPES OF SCREWS AND PERTAINING TOOLS

Since shapes and functions of components, machines, apparatuses, and implements are different, screws must be different too. This often gives rise to the necessity of using different tools for tightening or loosening the screws. Therefore, everything depends on the correct choice of (1) the type of screws and (2) of tools for the purpose in question.

1. Types of screws

The following screws, which are characterized by a fine pitch of thread, serve to fasten components.

Slotted screws

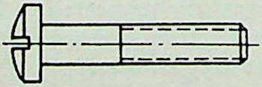


Fig. 224 Lense head screw

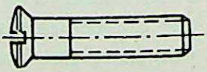


Fig. 225 Lense head countersunk screw

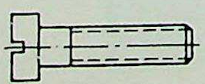


Fig. 226 Fillister head screw

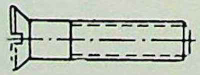


Fig. 227 Countersunk screw

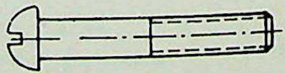


Fig. 228 Half-round screw

Non-slotted screws

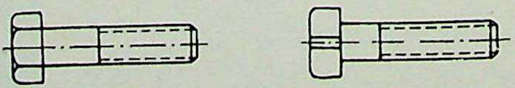


Fig. 229 Hexagon head screw and square head screw with shoulder

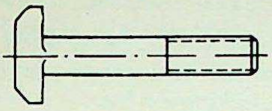


Fig. 230 Hammer head screw

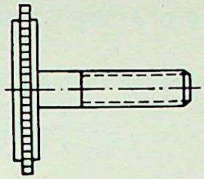


Fig. 231 Knurled flat head screw

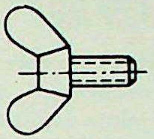


Fig. 232 Thumb screw

2. Tools

The tools for tightening and unscrewing screw joints include the screw driver and the spanner. In any case, it is of particular importance that the tool to be used should match to the size of the screw (or nut) in question. When unsuitable tools are used, the screw slot may be destroyed.

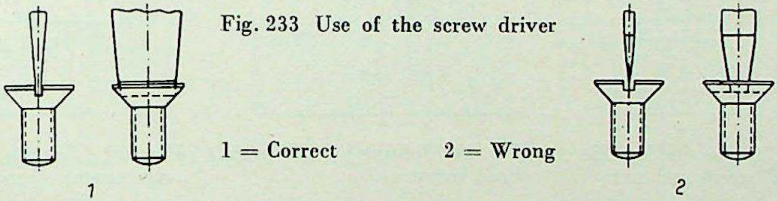


Fig. 233 Use of the screw driver

1 = Correct 2 = Wrong

As to spanners, their jaws also must match to the screw size. Adjustable spanners must be set to the screw size involved. The length of spanners ensures that any screw is satisfactorily tightened by the force applied. The use of extension pieces, such as tubes slipped on to a spanner, is not permissible because screws easily may break with too great a force exerted.

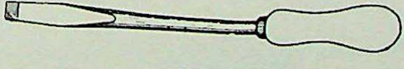


Fig. 234 Screw driver

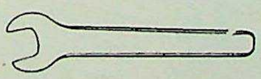


Fig. 235 Plane spanner

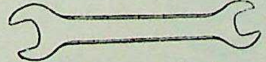


Fig. 236 Double-ended spanner

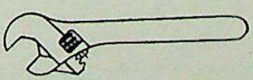


Fig. 237 Adjustable spanner

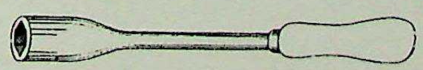


Fig. 238 Box spanner

II. FREQUENTLY USED SCREW JOINTS

There are different ways of connecting components by screws. Some screw joints are used very often. They are illustrated below and distinguished into (1) joints without locking device and (2) joints with locking device.

1. Joints without locking device

Screw joints with the joining elements (screws, bolts, nuts) directly contacting the components to be joined are called joints without locking device.

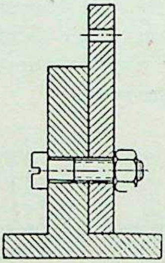


Fig. 239 Joining by fillister head screw and nut

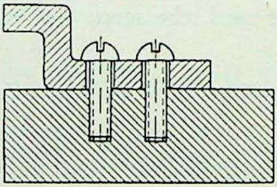


Fig. 240 Joining by half-round head screw

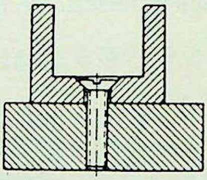


Fig. 241 Joining by countersunk screw

2. Joints with locking device

Screw joints were additional nuts, toothed washers or spring rings are inserted between the joining elements and the component are called joints with locking device. A specific type of locking devices is the castle nut with cotter pin. The cotter pin is put through a hole provided in the bolt in such

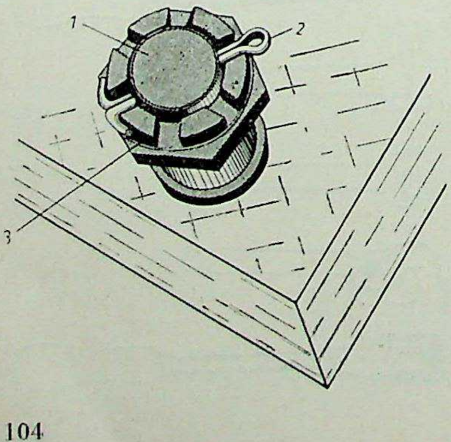


Fig. 242 Castle nut with cotter pin

1 = Threaded bolt with cotter pin hole

2 = Cotter pin

3 = Castle nut

a way that the ends of the pin projecting from the bolt fit into recesses in the castle nut. Such locking arrangements are frequently used in the steering linkage of motorcars.

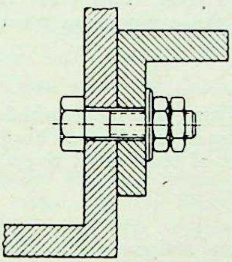


Fig. 243 Joining by hexagon head screw, nut, and counter-nut

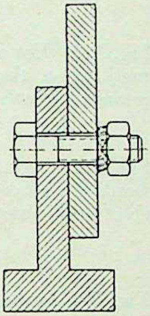


Fig. 244 Joining by hexagon head screw, nut, and toothed washer

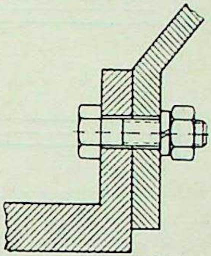


Fig. 245 Joining by hexagon head screw, nut, and spring ring

O. JOINING BY RIVETS

Rivets are used to join such components as, by their nature or function, are never to be parted. We distinguish between fixed rivet joints and movable rivet joints. With fixed rivet joints, the joined components closely contact each other; movable rivet joints enable the components to be moved after riveting (for example the riveted hinge of tongs).

I. CHOICE OF TYPES OF RIVETS AND PERTAINING TOOLS

Shapes and functions of components, machines, apparatuses, and implements determine the type of rivet to be used. Also the riveting tools should be selected in conformity with the type of rivet used. We distinguish in determining (1) the type of rivet and (2) the tools to be used.

1. Types of rivets

The seller of commercial rivets states shape of head, diameter, and length of the rivet. The shape of the rivet head is to be selected according to the intented use of the work piece to be riveted. The diameter to be selected is dependent on the required strength and thickness of the components to be riveted. The length of the rivet must, above all, correspond to the thickness of the components to be joined.

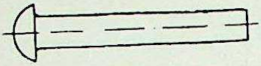


Fig. 246 Button head rivet. This rivet is used where high strength is required. This applies to steel constructions.

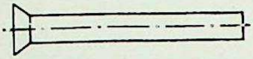


Fig. 247 Countersunk head rivet. This rivet is used when the surface of the components must remain smooth.

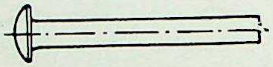


Fig. 248 Truss head rivet. Thin sheet-metal which would be weakened by the use of countersunk head rivets are riveted by means of truss head rivets.

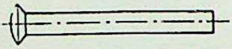


Fig. 249 Lens heat rivet. Steel staircases and steel ladders are riveted by means of lens head rivets if their thread must be slip-proof.

2. Tools

In general, it is distinguished between hot and cold riveting. Hot riveting requires the rivet to be heated so that the head can be set in red hot condition. Hot riveting is used when rivets with a diameter over 8 mm. must be used. This method of riveting requires riveting tongs for gripping and holding the hot rivets, in addition to the tools mention below. The following tools refer to cold riveting.

Fig. 250

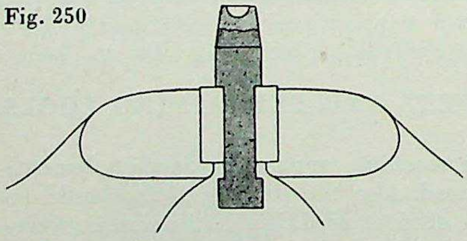


Fig. 251

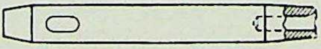


Fig. 252

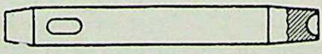


Fig. 250 Holder-on for cutton head rivets
The holder-on is chucked in a vice and serves to hold the set head of the rivet.

Fig. 251 Rivet set
The rivet set has drill a hole into which the rivet body projects

Fig. 252 Snap die
This tool is provided with a recess in its lower part which determines the shape of the snap head of the rivet. The top of the snap die is rounded to prevent the riveting hammer from slipping off.

II. UNDRIVEN RIVET AND DRILL HOLE DIAMETER

The dimensions of the undriven rivet must be calculated according to the thickness of the components be riveted.

1. Calculating the undriven rivet size

Calculating the undriven rivet size means determining the diameter and the body length of the rivet.

Calculating the diameter of the undriven rivet

If, for example, 15 mm. thick sheet steel is to be riveted with a 5 mm. thick sheet steel, the total thickness of the sheet to be riveted amounts 20 mm. This thickness is called length of grip (abbreviation s).

Generally, the diameter of an undriven rivet should amount to one fourth of the length of grip, that is,

$$\text{diameter of undriven rivet} = \frac{\text{length of grip}}{4} \quad \text{or} \quad d_R = \frac{1}{4}s$$

When we assume the length of grip s to be 20 mm., the diameter of the undriven rivet is

$$d_R = \frac{20\text{ mm.}}{4} = \underline{\mathbf{5\ mm.}}$$

Calculating the length of the rivet body

If the total length of a rivet would be equal to the length of grip, no snap head could be formed. Hence, the length of the rivet body must be larger than the length of grip. The actual value of the body length is dependent on (1) the type of the snap head (for example button head or countersunk head) and (2) the diameter of the undriven rivet. The rivet body length is obtained when we add an allowance for the snap head to the length of grip, hence

rivet body length = length of grip + allowance for the snap head

or

$$l_N = s + z$$

First, let us determine the allowance for a button head rivet. It works out at 1.5 times the value of the undriven rivet diameter d_R,

hence

$$z = d_R \times 1.5$$

Assume the undriven rivet diameter to be, for example, 5 mm., then

$$z = 5\text{ mm.} \times 1.5 = \underline{\mathbf{7.5\ mm.}}$$

Hence it follows that the total length of the rivet body is

$$l_N = 20\text{ mm.} + 7.5\text{ mm.} = \underline{\mathbf{27.5\ mm.}}$$

When the snap head allowance for a countersunk head rivet is to be determined we must take into account an approximate value for this allowance which is as followes:

$$z = d_R \times 0.5$$

In other words, half of the value of the undriven rivet diameter must be added to the length of grip. Related to this example, this means that

$$l_N = 20\text{ mm.} + 2.5\text{ mm.} = \underline{\mathbf{22.5\ mm.}}$$

2. Tables of rivets

Button head rivet with button snap head used in steel construction

Diameter of rivet (d)	10	12	16	20	22	24	27	30	36
	Length of rivet (l)								
Length of grips (s)									
10	26	28							
12	26	28	32						
16	32	34	38	40					
18	34	36	40	45	48				
20	38	38	42	48	50				
22	40	40	45	50	52	55			
28	48	48	52	58	60	62	65		
32	50	52	58	62	65	68	70	72	
36	55	58	62	68	70	72	75	78	
40	60	62	68	72	75	78	80	82	85
44		65	70	75	78	80	82	85	95
50			78	82	85	85	90	90	100
56			85	90	90	95	95	100	105
62			90	95	100	100	105	105	115
70				105	110	110	110	115	120
80				115	120	120	125	130	135
90				130	135	135	135	140	145
100						145	150	150	155

Button head rivet with countersunk snap head used in steel construction

Diameter of rivet (d)	10	12	16	20	22	24	27	30	36
	Length of rivet (l)								
Length of grip (s)									
10	16								
12	18	20							
16	24	24	26						
18	26	26	28	30					
20	28	30	32	32	34				
22	32	32	34	36	36				
28	40	40	40	42	42	45	45		
32		45	45	48	48	50	50	52	
36		50	50	52	52	55	55	58	
40		55	55	58	58	58	60	60	
44			60	62	62	62	62	62	62
50			68	68	68	70	70	70	70
56			75	75	75	78	78	78	78
62				85	85	85	85	85	85
70				95	95	95	95	95	95
80					105	105	105	105	105
90						115	115	115	115
100							130	130	130

Drill hole diameter required for rivets from 1 to 10 mm.

Diameter of undriven rivet d_R in millimetres	1	1.4	1.7	2	2.3	2.6	3	3.5	4	5	6	7	8	9	10
Drill hole diameter d_B in millimetres	1.1	1.5	1.8	2.2	2.5	2.8	3.2	3.7	4.3	5.3	6.4	7.4	8.4	9.5	11

III. WORKING WITH THE RIVETING TOOLS

When rivet joints of button head rivets are to be made, the riveting tools must be used which are described on page 106. After drilling and burring the rivet holes, the undriven rivet is inserted in the hole through the parts to be

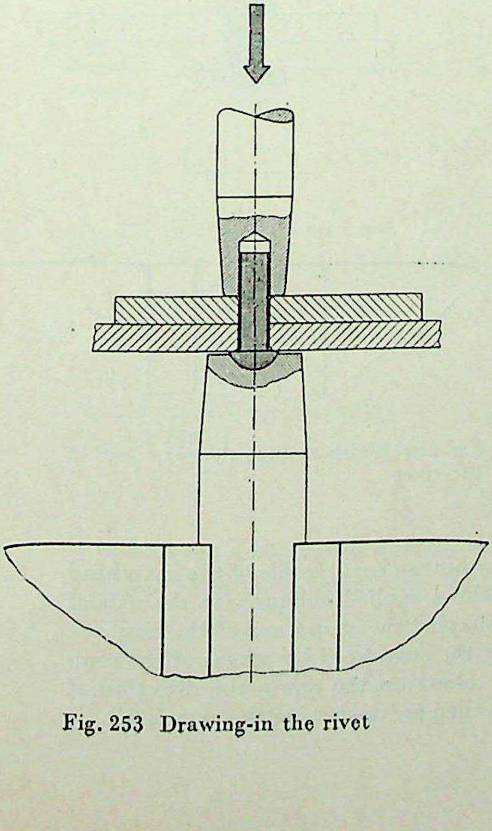


Fig. 253 Drawing-in the rivet

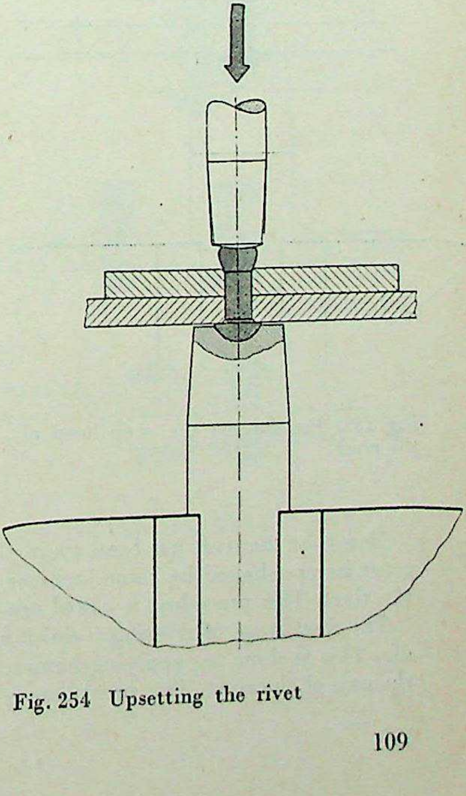


Fig. 254 Upsetting the rivet

joint and the set head of the rivet is put into the holder-on. The holder-on should be chucked in a vice or must otherwise be arranged in such a way that it provides for a firm, not resilient support for the set heads.

Then the rivet set is slipped on to the projecting end of the rivet body. A few strong blows of the hammer applied to the rivet set cause the set head of the rivet and the parts to be riveted to make a close contact. This preliminary procedure is called drawing-in the rivet.

Once the rivet is drawn-in, some hammer blows are applied to the rivet body in the direction of its axis. In this way the rivet body will be upset. This procedure is called upsetting the rivet.

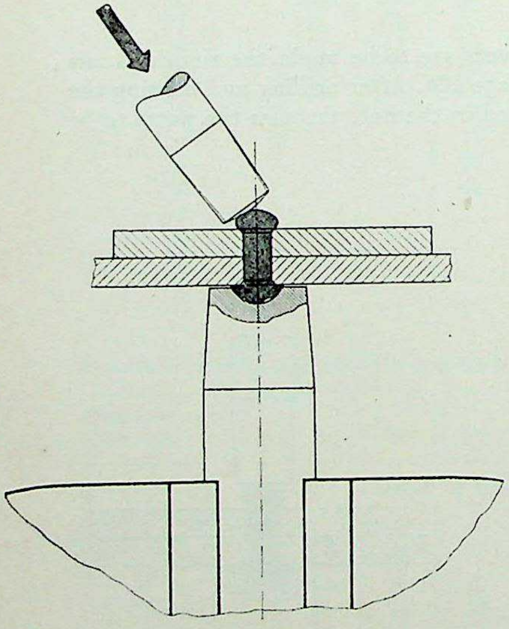


Fig. 255 Pre-shaping the snap head of the rivet

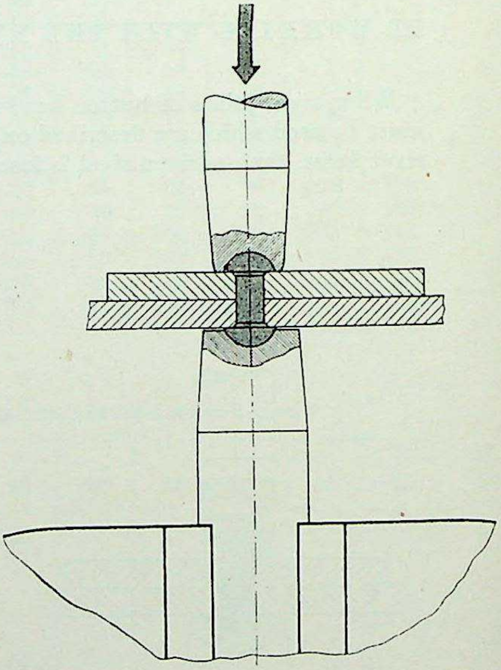


Fig. 256 Finish-shaping the snap head of the rivet

Now that the rivet has been upset, the button head profile of the snap head must be pre-shaped by some hammer blows applied obliquely to the axis of the rivet. This procedure is called pre-shaping the snap head of the rivet.

The final stage of riveting is finishing the snap head by means of the snap die. This is done by applying hammer blows on the die in the direction of the axis of the rivet. This procedure is called finish-shaping the snap head.

When countersunk head rivets are to be used, profiled holder-on and snap die are not used. In such cases, frequently a simple riveting plate is used instead of the holder-on, and the snap head of the countersunk rivet is formed by means of the hammer.

IV. SURVEY OF USUAL RIVET ARRANGEMENTS WITH FIXED RIVET JOINTS

The way of arranging rivets is mostly dependent on the function of th work piece to be riveted. For example, the construction of tanks requires *fluid-tight* rivet joints which are characterised by many rivets of small diameters. On the other hand, boiler construction where higher pressures are involved require *fluid-tight* and very *solid* rivet joints. Such rivet arrangements are characterised by many rivets of large diameter. It must be pointed out that all rivet work calls for a strict observance of the instructions given in the workshop drawing.

The following examples illustrate rivet arrangements which are frequently used in practice.

Fig. 257 Single-row lap joint riveting

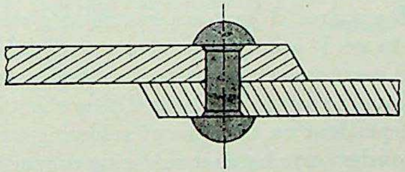


Fig. 258 Single-row butt rivet joint

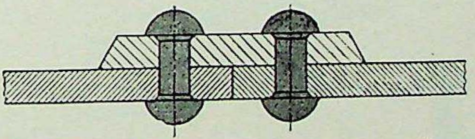
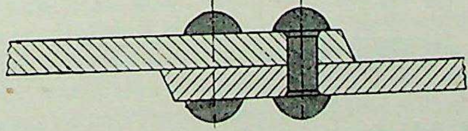


Fig. 259 Double-row zigzag lap joint riveting



To prevent accidents in riveting observe the following hints.

Before starting riveting make sure that

(1) the hammer is fixed firmly in the head,
(2) the holder-on is properly chucked and supported,
(3) the drill holes are burred,
(4) the length of the rivet body is correct.

P. JOINING BY SOFT SOLDERING

Soft soldering is a method to produce permanent joints on work pieces of metal. These joints are obtained by adding a tinny binder in molten state between the work pieces which penetrates into the superficial structure of work pieces and joins them when hardening.

I. SOLDERING TOOL AND AUXILIARIES

Most of the soft soldering work required in practice is done by using a soldering copper or iron. The various types of soldering tools are subdivided into (1) soldering tools without own source of heat and (2) soldering tools with own source of heat. Furthermore, (3) soldering auxiliaries should be dealt with in this connection.

1. Soldering tools without own source of heat

The common feature of this type of soldering tools is that the hammer performing the actual soldering operation is made of copper, and, when hot, melts the binder. Soldering copper bits (or hammers) which are not provided with a source of heat are heated in a wood fire or coal fire or by means of a gas flame. It is only natural that such soldering copper bits quickly cool down. This means that they permit soldering during short periods only. The copper bit must be repeatedly heated after short intervals. The shape of the copper bit is dependent on the type of soldering work to be performed and can be distinguished into hatchet soldering copper bits and pointed soldering copper bits.

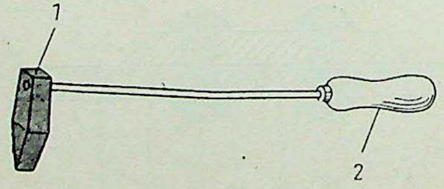


Fig. 260 Hatchet soldering copper bit
1 = Copper bit
2 = Handle

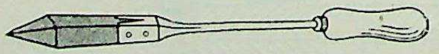


Fig. 261 Copper bit of the pointed soldering tool

2. Soldering tools with own source of heat

Best results can be obtained when working with soldering tools provided with a source of heat because the soldering operations need then not be interrupted for re-heating, as is the case with the above mentioned soldering coppers.

Directly heated soldering tools are subdivided into electrically heated soldering irons, soldering irons operated on gas and such operated on fuel. However, these soldering irons, in particular those operated on gas or fuel, show the disadvantage of a greater weight.

3. Soldering auxiliaries

Auxiliaries for soldering tools and soldering operations are the soldering tool holder, the solder, and the soldering flux.

Soldering tool holder

It may be necessary to interrupt the work and to put the soldering tool down. In this case it is always indicated to place the soldering iron or copper on a holder. The holder prevents the work bench from being burnt and reduces heat dissipation.

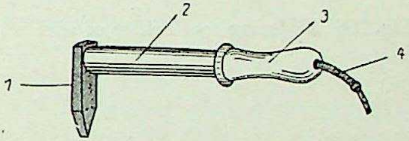


Fig. 262 Electrically heated soldering iron
1 = Soldering hammer
2 = Heating cartridge
3 = Handle
4 = Power supply cable

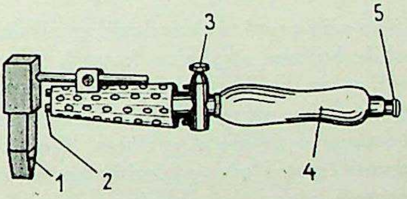


Fig. 263 Soldering iron operated on gas
1 = Soldering hammer
2 = Nozzles
3 = Adjusting screws
4 = Handle
5 = Connecting piece

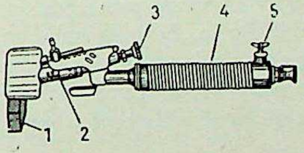


Fig. 264. Soldering iron operated on fuel
1 = Soldering hammer
2 = Nozzles
3 = Adjusting screw
4 = Handle designed as fuel tank
5 = Tank inlet

Solder

The solder for soft soldering usually is an alloy of zinc and lead. The percentage of zinc and lead in a solder compound is dependent on the kind of soldering work to be done and the materials to be joined. Soldering joints applied in tank and container construction require a solder with a very high percentage of zinc, in particular when containers for the preservation of food are to be soldered.

Soldering flux

Soldering flux serves to destroy the oxide film formed when metal is heated. The solder refuses to flow on a hot metal surface when an oxide film is present. Muriatic acid, soldering fluid, soldering paste, and soldering rosin are types of soldering flux. Muriatic acid only is used when sheet zinc is soldered. Soldering fluid can be made in the following way: Fill muriatic acid

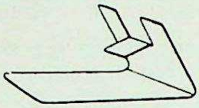


Fig. 265 Soldering tool holder of sheet-metal

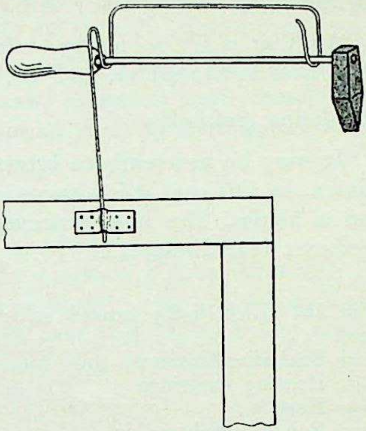


Fig. 266 Soldering tool holder of wire

in an acid-proof tank and add small pieces of sheet zinc which will be dissolved while bubbles are being formed. After some time the formation of bubbles will cease. This means that the soldering fluid is ready. The main components of soldering paste are rosin and ammoniac salt. The paste can conveniently be applied to metal surfaces. The only disadvantage is that the soldering points treated with soldering paste cannot be cleaned easily. When soldering paste is left on the soldering point, it is possible that the metals are gradually destroyed by chemical processes, in other words, "the metals are being decomposed". Rosin, both in solid and viscous state, is preferably used for soldering electrical connections. Contrary to the above mentioned types of soldering flux, no undesired by-effects on the electrical properties of the materials soldered will occur when rosin is used.

II. WORKING WITH THE SOLDERING IRON OR COPPER

When handling soldering tools, several operations are necessarily repeated which are dealt with below in the following sequence: (1) tinning the soldering hammer, (2) cleaning the soldering point and application of soldering flux, (3) holding the parts to be soldered, and (4) tacking a seam.

1. Tinning the soldering hammer

When a soldering hammer is heated, an oxide film is being formed which refuses to accept the solder. Therefore, the hot soldering hammer must be freed from the oxide film. This must be done quickly by some file strokes and by an immediate application of solid sal ammoniac to the point of the soldering hammer or by immediate immersion into the fluid soldering flux. Then the solder must be applied to the hammer in such a way that the melting solder is tinning its point. The remainders of the flux can easily be wiped off by means of a folded wet cloth.

2. Cleaning the soldering point and application of the soldering flux

Metal surfaces which are to be joined by means of solder must carefully be cleaned. Files or scrapers are used for this end, sometimes abrasive paper or cloth can also be used with best results. Once the metal surfaces have been treated in this way, they should not be touched with your hand because sweat will prevent the solder from flowing.

The liquid or solid flux is applied to the cleaned metal surface. It is pointed out that the flux must be used economically because not the quantity applied but the uniform distribution of flux on the soldering point is the decisive factor. Take care when using muriatic acid as soldering flux, because part of your skin or, eventually, your eyes may be cauterized through inadvertence.

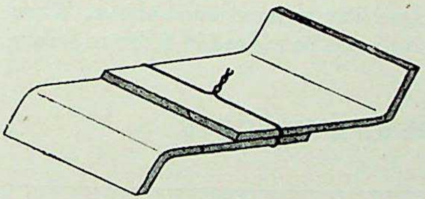


Fig. 267 Parts to be soldered held by means of wire

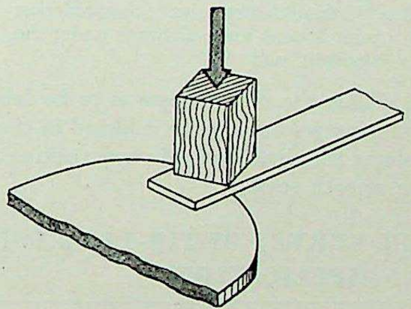


Fig. 268 Parts to be soldered held by means of a piece of wood

3. Holding the parts to be soldered

In many cases metals are worked while they are chucked in the vice. This is, however, not possible with soldering work because of the excessive heat dissipation involved. Therefore, the parts to be treated are held by means of wire or a piece of wood.

4. Soldering seam

There are two ways of producing a longer soldering point, the so-called soldering seam, namely, *tacking* and *finish-soldering* the seam.

Tacking means that the parts to be soldered are connected by small soldering points applied at larger intervals. At the same time it is possible to check whether the parts remain to be in the desired position. The first thing to do in tacking is to hold the solder against the hot and tinned hammer until a small quantity of solder adheres to the hammer point.

Then the soldering hammer is held against the cleaned and flux-coated metal surface of the work pieces which are being held together until the solder flows from the soldering hammer on to the metal surfaces. The solder must be very fluid. A viscous or pasty solder applied to the soldering point will not penetrate into the surface of metals which means that the soldered joint is not strong enough. Viscous or pasty solder indicates that the soldering point has not properly been heated, in other words, this is a "cold soldering point", as people use to say.

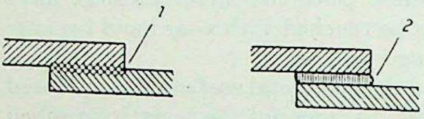


Fig. 269
1 = Proper soldering joint; the solder has penetrated the surface of the work pieces
2 = "Cold soldering point"; this soldering joint is weak and will break under the slightest load

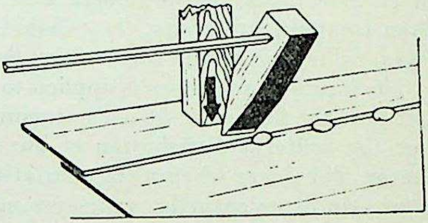


Fig. 270 Tacking seam

When the tacked seam is to be fully soldered, the intervalls between the tacking points must be soldered in the same way as mentioned above. When doing this, both ends of every tacking point must be melted in order to secure a smooth seam.

III. SURVEY OF TIN-LEAD SOLDERS AND THEIR APPLICATION

Designation	Percentage of		Application
	Zinc	Lead	
Tin-lead solder 30	30	70	Rough building plumber's work
Tin-lead solder 33	33	67	Soldering sheet zinc or galvanized sheet-metal
Tin-lead solder 40	40	60	Soldering thick brass sheet or tinned sheet-iron
Tin-lead solder 50	50	50	Soldering thin brass sheet or tinned sheet-iron
Tin-lead solder 60	60	40	Soldering quickly melting metals and electrical connections
Tin-lead solder 90	90	10	Soldering containers used to store or preserve food-stuffs